3 RISK ASSESSMENT

The risk assessment lays the foundation for the South Dakota Multi-Hazard Mitigation Plan. It sets the stage for identifying mitigation goals and activities to help the state become disaster resilient and keep South Dakota residents safe. The major components of this risk assessment include a hazard identification/analysis and a vulnerability analysis that answer the following questions: What are the hazards that could affect South Dakota? What can happen as a result of those hazards? How likely is each of the possible outcomes? When the possible outcomes occur, what are the likely consequences and losses, and how does this vary across the state? This section attempts to answer these questions on a hazard by hazard basis based on best available data.

The Federal Emergency Management Agency (FEMA) defines risk assessment terminology as follows:

- **Hazard**—A hazard is an act or phenomenon that has the potential to produce harm or other undesirable consequences to a person or thing.
- **Vulnerability**—Vulnerability is susceptibility to physical injury, harm, damage, or economic loss. It depends on an asset's construction, contents, and economic value of its functions.
- **Exposure**—Exposure describes the people, property, systems, or functions that could be lost to a hazard. Generally, exposure includes what lies in the area the hazard could affect.
- **Risk**—Risk depends on hazards, vulnerability, and exposure. It is the estimated impact that a hazard would have on people, services, facilities, and structures in a community. It refers to the likelihood of a hazard event resulting in an adverse condition that causes injury or damage.
- **Risk Assessment**—Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from hazards.

3.1 IDENTIFYING HAZARDS

44 CFR Part 201 Requirement:
[The State risk assessment shall include an] overview of the type…of all natural hazards that can affect the State…

The following resources were used to identify hazards that may affect the State of South Dakota:

- Federal disaster/emergency declarations (see Table 3-4)
- State Hazard Mitigation Team and South Dakota Silver Jackets members
- Local hazard mitigation plans covering all 66 counties and 3 tribal governments
- Public input via an online survey (2013)
- HAZUS-MH (see Sections 3.3–3.5)

The geography and climate of South Dakota are central to the hazards that affect the state. The following information is directly from NetState.com.

Geography

- **Longitude/Latitude**—Longitude: 97° 28' 33"W to 104° 3'W/Latitude: 42° 29' 30"N to 45° 56'N

- **Length x Width**—South Dakota is about 380 miles long and 210 miles wide.
- **Geographic Center**—The geographic center of South Dakota is located in Hughes County, 8 miles NE of Pierre (Longitude: 100° 28.7' W, Latitude: 44° 24.1' N).
- **Borders**—South Dakota is bordered by North Dakota on the north and by Nebraska on the south. On the east, South Dakota is bordered by Minnesota and Iowa. On the west, South Dakota is bordered by Montana and Wyoming.
- **Total Area**—South Dakota covers 77,121 square miles, making it the 17th largest of the 50 states.
- **Land Area**—75,898 square miles of South Dakota are land areas.
- **Water Area**—1,224 square miles of South Dakota is covered by water.
- **Highest Point**—The highest point in South Dakota is Harney Peak at 7,242 feet above sea level.
- **Lowest Point**—The lowest point in South Dakota is Big Stone Lake at 966 feet above sea level.
- **Mean Elevation**—The Mean Elevation of the state of South Dakota is 2,200 feet above sea level.
- **Major Rivers**—Cheyenne River, Missouri River, James River, White River, Big Sioux River
- **Major Lakes**—Lake Oahe, Lake Francis Case, Lewis and Clark Lake

The Missouri River runs through the central part of South Dakota. To the east of the river, low hills and lakes formed by glaciers are now fertile farms. To the west of the Missouri River, the land consists of deep canyons and rolling plains.

South Dakota is comprised of four major land regions; the Drift Prairie, the Dissected Till Plains, the Great Plains, and the Black Hills.

The **Drift Prairie** covers most of eastern South Dakota. This is the land of low hills and glacial lakes. This area was called Coteau des Prairies (Prairie Hills) by early French traders. In the north, the Coteau des Prairies is bordered on the east by the Minnesota River Valley and on the west by the James River Basin. The James River Basin is mostly flat, following the flow of the James River through South Dakota from north to south.

The **Dissected Till Plains** lie in the southeastern corner of South Dakota. This area of rolling hills is crisscrossed by many streams.

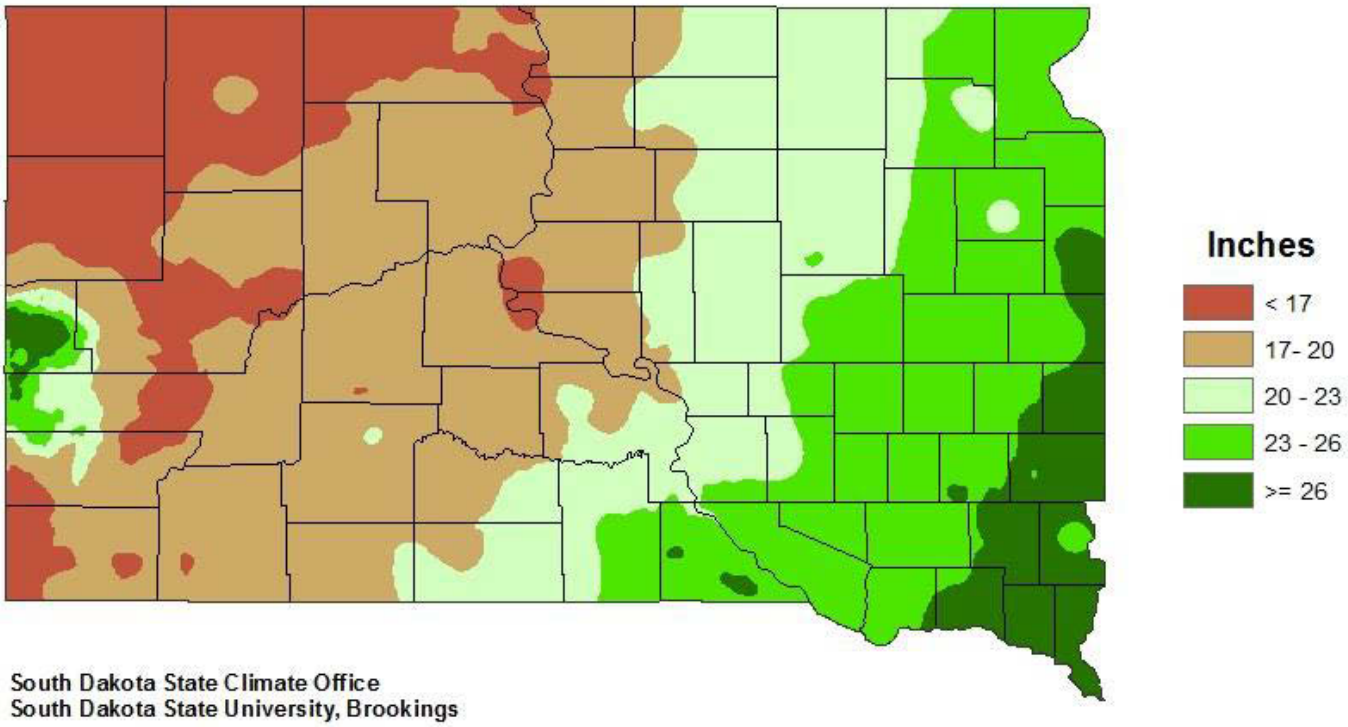
The **Great Plains** cover most of the western two thirds of South Dakota. The Coteau de Missouri hills and valleys lie between the James River Basin of the drift prairie and the Missouri River. West of the Missouri River the landscape becomes more rugged and consists of rolling hills, plains, canyons, and steep flat-topped hills called buttes. These buttes sometimes rise 400 to 600 feet above the plains. In the south, east of the Black Hills, lie the South Dakota Badlands. Badlands National Park is located here.

The **Black Hills** are in the southwestern part of South Dakota and extend into Wyoming. This range of low mountains covers 6,000 square miles with mountains that rise from 2,000 to 4,000 feet high. The highest point in South Dakota, Harney Peak (7,242 feet above sea level), is in the Black Hills. The Black Hills are rich in minerals such as gold, silver, copper, and lead.

Climate

- **Highest Temperature**—The highest temperature recorded in South Dakota is 120°F. This record high was recorded on July 5, 1936 at Gann Valley, and tied on July 16, 2006 in Usta.
- **Lowest Temperature**—The lowest temperature in South Dakota, -58°F, was recorded on February 17, 1936 at McIntosh.
- **Average Temperature**—Monthly average temperatures range from a high of 86.5°F degrees to a low of 1.9°F degrees.
- **Climate**—Average yearly precipitation for South Dakota, from 1971 to 2000, is shown in Figure 3-1.

Figure 3-1: South Dakota's Average Annual Precipitation 1981-2010



Methodology

Based on past disaster history and population and property potentially at risk (numbers and dollars), the following hazards have emerged as the greatest concern statewide and are profiled in detail in this plan:

- Agricultural Pests and Diseases
- Drought
- Floods (flash, long-rain, snowmelt, and dam failure or levee failure floods)
- Summer Storm
- Winter Storm
- Wildfire
- Drought
- Tornado
- Windstorm
- Hazardous Materials
- Geological Hazards (Landslides, Mudflows, Expansive Soils, Subsidence, and Earthquakes)

During the 2014 hazard mitigation plan update, the State Hazard Mitigation Team (SHMT) reexamined these hazards that threaten South Dakota. During the 2014 plan update process, the SHMT discussed adding a hazard profile for Summer Storms to align with local plans. While flooding from severe thunderstorms is addressed in the flood hazard profile, this hazard profile would include hail and lightning. Microburst wind associated with thunderstorm is already addressed in the wind profile. The SHMT recommended that Summer Storms should be added as a new hazard profile during the next plan update, so the 2016 HIRA update includes this new hazard profile. The Summer Storms hazard profile includes hail and lightning. Extreme heat is addressed in the drought hazard profile, and extreme cold is part of the winter storm hazard.

The following natural hazards are not included in this analysis because they do not threaten South Dakota: avalanches, coastal erosion, coastal storms, hurricanes, tsunamis, and volcanoes.

Non-Natural Hazards

The State Hazard Mitigation Team determined not to include human-caused and technological hazards in this plan. The State's Threat and Hazard Identification and Risk Analysis (THIRA), originally developed in 2012 and updated periodically, is an all hazards risk assessment that analyzes the State's capabilities toward addressing natural, human-caused, and technological hazards. The THIRA was developed in compliance with the US Department of Homeland Security Comprehensive Preparedness Guide 201 by a committee lead by the State's Office of Homeland Security. The THIRA includes hazard profiles for the most pertinent human-caused and technological hazards intended to supplement the natural hazards profiled within this Multi-Hazard Mitigation Plan. Further information regarding the THIRA may be obtained by contacting the State's Office of Homeland Security.

Prioritizing Hazards

A similar hazard ranking exercise as used in the previous plan update was used by the State Hazard Mitigation Team to validate and rank the hazards during the 2016 HIRA update. The ranking methodology includes risk considerations from local plans and input from a 2013 public survey. The hazards of greatest significance were identified to be flooding, winter storms, wildfires, and drought. Tornadoes, wind, summer storms, and agricultural pests and diseases were ranked as moderate. Tornadoes, ranked as significant in the 2011 plan update, were found to be moderate for this update. Geological hazards, including earthquake, were also downgraded from moderate in 2011 and ranked as a limited hazard in 2014. Significance rankings remained the same during the 2016 HIRA update.

Prioritization of the hazards that threaten the state was based on four factors: probability, potential impact, consideration in local hazard mitigation plans, and survey input. The likely geographical extent of the affected area, primary impacts of the event, and related secondary impacts all factor into the overall potential impact. While primary impacts are a direct result of the hazard, secondary impacts can only arise subsequent to a primary impact. For example, a primary impact of a flood event may be road damage due to submerged pavement or eroded surface. A possible secondary impact in these circumstances would be restricted access of emergency vehicles to citizens in a particular area due to the road closure.

A formula was developed to assign a value for probability and impact for each of the hazards considered. The probability of each hazard was determined by assigning a level, from 1 to 4, based on the likelihood of occurrence (which is based on historical data). Similarly, levels from 1 to 4 were assigned to each of the three impact factors mentioned above. Probability and impact factor levels assigned to each hazard were each then multiplied by an importance factor.

To incorporate the consideration of these hazards in local plans, the number of local plans that included the hazard was divided by 68 (total local and tribal plans within the State) and multiplied by 10 to create a Local Plans Score on a scale of 0 -10.

Survey respondents rated the hazards on a scale of 1 – 3. The average rating was divided by 3 and multiplied by 10 to create a Survey Score on a scale of 1-10.

The total hazard ranking score was calculated as follows:

[(Probability x 2) x [(Affected Area x 0.8) + (Primary Impact x 0.7) + (Secondary Impacts x 0.5)]] + Local Plans Score + Survey Score

Based on the total calculated score, the hazards were separated into three categories that describe the relative risk level they pose to the state: high significance, moderate, and limited. These terms relate to the level of planning analysis to be given to the particular hazard in the risk assessment process and are not meant to suggest that a hazard would have only limited impact. In order to focus on the most critical hazards, those assigned a level of high significance or moderate were given more extensive attention in the remainder of this analysis (e.g., quantitative analysis or loss estimation), while those with a limited planning consideration were addressed in more general or qualitative ways.

The hazard ranking was based on the overall probability and impact on the state as a whole. When examining various regions of the state, the same ranking does not always apply. Table 3-1 summarizes the ranking established by the state using the method described above.

Table 3-1: Hazard Ranking and Planning Consideration

Hazard Type and Ranking		Planning Consideration Based on Hazard Level
1	Flooding (flash, long-rain, snowmelt, and dam or levee failure)	Significant
2	Winter Storms	Significant
3	Wildfires	Significant
4	Drought	Significant
5	Tornadoes	Significant
6	Summer Storms	Moderate
7	Wind	Moderate
8	Agricultural Pests and Diseases	Moderate
9	Hazardous Materials	Moderate
10	Geological Hazards (Landslide, Mudflow, Expansive Soils, Earthquake)	Limited

A Hazard Identification and Ranking Worksheet is included on the following page and contains the calculations and formulas utilized during the 2016 update.

Table 3-2 Hazard Ranking Worksheet – South Dakota

Hazard Type	Probability	Impact			Local Plans	Survey Rating	Local Plans Score	Survey Score	Total Score	Hazard Planning Consideration
		Affected Area	Primary Impact	Secondary Impacts						
FLOODING	4	4	2	3	66	1.73	9.71	5.75	64.26	**High Significance**
WINTER STORMS	4	4	2	3	67	2.49	9.85	8.30	66.95	**High Significance**
WILDFIRES	4	2	4	3	59	1.94	8.68	6.47	62.34	**High Significance**
DROUGHT (including Extreme Heat)	4	3	2	4	45	2.39	6.62	7.97	60.98	**High Significance**
TORNADOES	4	1	4	4	43	2.12	6.32	7.07	58.19	**Moderate**

SUMMER STORMS	4	2	2	2	31	1.94	4.70	6.47	43.16	**Moderate**
WIND	4	2	2	2	28	2.19	4.12	7.30	43.42	**Moderate**
AGRICULTURAL PESTS/DISEASES	3	3	1	4	3	1.85	0.44	6.17	37.21	**Moderate**
HAZARDOUS MATERIALS*	4	1	1	3	41	1.79	6.03	5.97	36.00	**Moderate**
GEOLOGICAL HAZARDS	3	2	1	2	15	1.18	2.21	3.92	25.92	**Limited**

Table 3-3 Hazard Ranking Legend

Probability	**Importance**	**2.0**
Based on estimated likelihood of occurrence from historical data		Score
Unlikely (Less than 1% probability in next 100 years or has a recurrence interval of greater than every 100 years.)		1
Somewhat Likely (Between 1 and 10% probability in next year or has a recurrence interval of 11 to 100 years.)		2
Likely (Between 10 and 100% probability in next year or has a recurrence interval of 10 years or less.)		3
Highly Likely (Near 100% probability in next year or happens every year.)		4

Secondary Impacts	**Importance**	**0.5**
Based on estimated secondary impacts to community at large considering economic impacts, health impacts, and crop losses		Score
Negligible - no loss of function, downtime, and/or evacuations		1
Limited - minimal loss of function, downtime, and/or evacuations		2
Moderate - some loss of function, downtime, and/or evacuations		3
High - major loss of function, downtime, and/or evacuations		4

Affected Area	**Importance**	**0.8**
Based on size of geographical area of community affected by hazard		Score
Isolated		1
Small		2
Medium		3
Large		4

Local Plans Score	**Importance**	**1.0**
Local Plans Score = (# of plans / 68) x 10 where:		
# of plans includes local and tribal plans within South Dakota that identified the hazard		

Primary Impact	**Importance**	**0.7**
Based on percentage of damage to typical facility in community		Score
Negligible - less than 10% damage		1
Limited - between 10% and 25% damage		2
Critical - between 25% and 50% damage		3
Catastrophic - more than 50% damage		4

Survey Score	**Importance**	**1.0**
Survey Score = (Survey Rating / 3) x 10 where:		
Survey Rating is the average rating of concern based on a scale of 1 (low concern) to 3 (high concern) compiled from the survey responses.		

Total Score = (Probability x Impact) + Local Plans Score +Survey Score, where:
Probability = (Probability Score x Importance)
Impact = (Affected Area + Primary Impact + Secondary Impacts), where:
Affected Area = Affected Area Score x Importance
Primary Impact = Primary Impact Score x Importance
Secondary Impacts = Secondary Impacts Score x Importance

Hazard Planning Consideration	**Total Score Range**
Limited	0 - 30
Moderate	30.1 - 60
Significant	60.1 - 90

As shown in the Hazard Ranking Worksheet, the majority of the local plans identified hazards consistently with those prioritized by the SHMT. Several additional hazards were identified by the local plans. Documentation of these hazards followed by the number of plans that identified each hazard is listed here for future reference by the State Hazard Mitigation Team, should these hazards become a statewide concern. While these are not explicitly profiled in this plan, the State Hazard Mitigation Team and the State Hazard Mitigation Officer will use this information to continue working with the local communities to understand the concerns these hazards pose, how they are in part already addressed by the state plan, and how they can be mitigated:

- Summer Storms (30)
- Hail (23)
- Civil Disturbances (22)
- Thunderstorms (20)
- Urban Fire (19)
- Mass Casualty Incident (18)
- Infectious Disease/Epidemic (17)
- Ice Storms (15) (see winter storms)
- Aviation Incident (15)
- Lightning Strike (13)

It must be noted that 37 of the 66 counties and 2 tribal governments identified terrorism as a risk. The State Hazard Mitigation Team recognizes this risk and feels that on a statewide level, terrorism is being mitigated to the best of their ability by the South Dakota Office of Homeland Security. As described above, the State's THIRA is the appropriate vehicle for addressing the measures being taken in South Dakota to fight terrorism and other human-caused and technological hazards, such as civil disturbances and mass casualty incidents listed above.

Presidential Declarations

Table 3-4 summarizes presidential disaster declarations, fire management assistance declarations, and emergency declarations for South Dakota since 1954- mid 2016. Forty-five presidential declarations in this 62-year period indicate that roughly every two years a disaster is declared. Since the early 1990's the state has had a presidential declaration on nearly an annual basis. From May 2013 to July 2016, South Dakota received five Presidential Disaster Declarations.

Table 3-4: Presidential Declarations

Declaration Number	Declaration Date	Counties (#)	Disaster Type	FEMA Disaster Relief Costs[1] (federal share)
FEMA-4233-DR	7/30/2015	11 counties	Severe Storms, Tornadoes, Straight-line Winds, and Flooding	$3,027,911*
FEMA-4186-DR	7/28/2014	11 counties	Severe Storms, Tornadoes, and Flooding	$10,670,243*
FEMA-4155-DR	11/8/2013	11 counties	Severe Winter Storm, Snowstorm, and Flooding	$41,758,316*
FEMA-4137-DR	8/2/2013	8 counties	Severe Storms, Tornado, and Flooding	$1,178,083*
FEMA-4125-DR	6/28/2013	4 counties	Severe Storms, Tornado, and Flooding	$1,321,339*
FEMA-4115-DR	5/10/2013	7 counties	Severe Winter Storm and Snowstorm	Unknown
FEMA-1984-DR	5/13/2011	28 Counties	Severe Storms and Flooding	$47,643,032
FEMA-1947-DR	11/2/2010	4 Counties (including 1 reservation within designated counties)	Severe Storms and Flooding	$1,067,415*
FEMA-1938-DR	9/23/2010	12 Counties	Severe Storms and Flooding	$4,551,087*
FEMA-1929-DR	7/29/2010	3 Counties (including 1 reservation within designated counties)	Severe Storms, Tornadoes, and Flooding	$725,128*
FEMA-1915-DR	5/13/2010	31 Counties	Flooding	$21,845,581*
FEMA-1914-DR	5/13/2010	3 Counties	Severe Winter Storm	$2,166,739*
FEMA-1887-DR	3/10/2010	29 Counties (including 3 reservations within designated counties)	Severe Winter Storm	$56,292,035*
FEMA-1886-DR	3/9/2010	12 Counties (including 2 reservations within designated counties)	Severe Winter Storm and Snowstorm	$866,846*
FEMA-1844-DR	06/16/2009	14 counties (including 2 reservations within designated counties and extending into North Dakota)	Severe Storms and Flooding	$5,222,817*
FEMA-1811-DR	12/12/2008	13 counties (including four reservations within designated counties)	Severe winter storm and record and near record snow	$5,825,275*

Declaration Number	Declaration Date	Counties (#)	Disaster Type	FEMA Disaster Relief Costs[1] (federal share)
FEMA-1774-DR	07/02/2008	26 counties (including portions of 3 reservations within designated counties)	Severe storms and flooding	$4,716,310*
FEMA-1759-DR	05/22/2008	6 counties	Severe winter storm and record and near record snow	$7,826,996*
FEMA-1702-DR	5/22/2007	24 counties (including 3 reservations within designated counties)	Severe Storms, Tornadoes, and Flooding	$8,373,536[2]
FEMA-1647-DR	6/5/2006	6 counties	Severe Winter Storm	$4,000,000[2]
FEMA-1620-DR	12/20/2005	26 counties	Severe Winter Storm	$28,000,000[2]
FEMA-1596-DR	7/22/2005	7 counties	Severe Storm (wind)	$840,159
FEMA-1531-DR	7/20/2004	9 counties, 1 reservation	Severe Storms and Flooding	$2,094,155
FEMA-1375-DR	5/17/2001	24 counties	Severe Storms (flooding)	$9,919,599
FEMA-1330-DR	5/19/2000	7 counties	Winter Storm	$2,877,023
FEMA-1280-DR	6/9/1999	2 counties	Severe Storms, Flooding, and Tornadoes	$17,848,761
FEMA-1218-DR	6/1/1998	9 counties	Flooding, Severe Storms, and Tornadoes	$15,953,312
FEMA-1173-DR	4/7/1997	66 counties	Severe Storms, Flooding (high winds)	$82,490,180
FEMA-1161-DR	2/28/1997	10 counties	Severe Winter Storms	$2,526,209
FEMA-1156-DR	1/10/1997	66 counties	Severe Winter Storms/Blizzards	$18,431,301
FEMA-1075-DR	1/5/1996	26 counties	Ice Storms	$12,431,366
FEMA-1052-DR	5/26/1995	52 counties	Severe Storms, Flooding	$33,866,882
FEMA-1045-DR	3/14/1995	21 counties	Severe Winter Storms	$3,627,131
FEMA-1031-DR	6/21/1994	21 counties	Severe Storm, Flooding.	$7,789,915
FEMA-999-DR	7/19/1993	39 counties	Flooding, Severe Storms, Tornadoes	$50,202,256
FEMA-948-DR	7/2/1992	9 counties	Flooding, Severe Storms, Tornadoes (high winds)	$1,669,825
FEMA-764-DR	5/3/1986	25 counties	Severe Storms, Flooding	$4,893,611
FEMA-717-DR	7/19/1984	9 counties	Severe Storms, Flooding	$4,216,001
FEMA-511-DR	6/25/1976	4 counties	Flash Flooding, Mudslides	$4,439,769
FEMA-336-DR	6/10/1972	4 counties	Heavy Rains, Flooding	$111,907,010

Declaration Number	Declaration Date	Counties (#)	Disaster Type	FEMA Disaster Relief Costs[1] (federal share)
FEMA-257-DR	4/18/1969	26 counties	Flooding	$4,369,737
FEMA-197-DR	5/26/1965	4 counties	Flooding	$3,771,780
FEMA-132-DR	7/27/1962	23 counties	Floods, Tornadoes	$3,652,937
FEMA-99-DR	4/8/1960	16 counties	Floods	$933,934
FEMA-20-DR	7/31/1954	2 counties	Floods	$252,255
FEMA-3234-EM	9/10/2005	All counties	Hurricane Katrina Evacuation	n/a
FEMA-3015-EM	6/17/1976	n/a	Drought	n/a
FEMA-5010-FM	9/1/2012	Oglala Lakota	Wellnitz Fire	Unknown
FEMA-2996-FM	7/20/2012	Custer	Myrtle Fire	Unknown
FEMA-2716-FSA	7/21/2007	Lawrence	Boxelder Fire	n/a
FEMA-2710-FSA	7/8/2007	Fall River	Alabaugh Canyon Fire	$2,659,373
FEMA-2658-FSA	7/27/2006	Meade	East Ridge Fire	$1,973,107
FEMA-2569-FSA	7/16/2005	Pennington	Skyline #2 Fire	$18,975
FEMA-2565-FSA	7/10/2005	Meade	Ricco Fire	$573,581
FEMA-2513-FSA	11/20/2003	Pennington	Mill Road Fire	$62,852
FEMA- 2458-FSA	8/18/2002	Pennington	Battle Creek Fire	$1,816,503
FEMA-2434-FSA	6/29/2002	Lawrence	Grizzly Gulch Fire	n/a
FEMA-2369-FSA	7/31/2001	Custer	Elk Mountain Fire	$293,000
FEMA-2324-FSA	8/25/2000	Custer	Jasper Fire	$2,500,000
FEMA-2319-FSA	8/13/2000	Fall River	Flagpole Fire	$1,750,000
FEMA-2109-FSA	8/16/1994	Meade	Stagebarn Canyon Fire	n/a
FEMA-2076-FSA	9/14/1990	Custer	Swedlund Fire	n/a
FEMA-2068-FSA	7/26/1988	Pennington	West Berry Trail Fire	n/a
FEMA-2061-FSA	7/22/1987	Fall River	Battle Mountain Fire	n/a
FEMA-2057-FSA	7/15/1985	Fall River	Flint Hill Fire	n/a
FEMA-2056-FSA	7/15/1985	Fall River	Seven Sisters Fire	n/a
FEMA-2017-FSA	7/29/1975	Custer	Custer State Park	n/a
FEMA-2016-FSA	7/8/1974	Custer	Argle & Booms Canyon	n/a

Sources: Federal Emergency Management Agency, South Dakota Office of Emergency Management, Public Entity Risk Institute
Notes:
[1]Costs include Public Assistance, Individual Assistance, and mitigation and are in constant 2006 dollars (with the exception disasters post-2006, which are year of event dollars). Fire costs are from the state, represent total outlays, and are not adjusted for inflation (with the exception of FEMA-2710-FSA, which is from InciWeb).
[2]Projects are not closed; costs are estimates from the state (FEMA-1702-DR is public assistance only).
*Includes Public Assistance only

Probability of Future Events

Predicting probability of future events is estimated by looking at the number of past damaging events, where possible (e.g. declared disasters), or using scientific estimates where available. Using the South Dakota information provided and the process as discussed in this section, one can conclude that it is probable that flooding, severe winter storms, tornadoes, wildfires, landslides/mudflows, and earthquakes will continue to occur in the future much as they have in the past. Some hazards are more likely to occur and cause more damage than others. This is discussed in more detail in the following hazard profiles.

Climate Change Exacerbation

FEMA's 2015 State Plan Review Guide emphasizes the need to discuss how future risk and vulnerability may be affected by changing climatic conditions. According to the guidance, probability must include considerations of changing future conditions, including the effects of long-term changes in weather patterns and climate on the identified hazards. While the intensity and frequency associated with the hazards profiled in this plan are largely based on historic events, climate change has the potential to alter the nature and frequency of hazard events in the future. A report on Global Climate Change Impacts in the United States was released by the U.S. Global Change Research Program (USGCRP 2009) in 2009 and summarizes the science of climate change and the impacts of climate change. The National Climate Assessment is a tool developed in 2014 that also addresses the impacts of climate change on the United States, now and in the future. A team of more than 300 experts guided by a 60-member Federal Advisory Committee produced the report, which was extensively reviewed by the public and experts, including federal agencies and a panel of the National Academy of Sciences. The reports discuss climate-related impacts for various societal and environmental sectors and regions across the nation. South Dakota lies within the Great Plains region. The science summarized in the reports point to increasing mean temperatures in the Great Plains. This will lead to increased evaporation and drought frequency, which will compound water scarcity problems. Increased demand for water and energy will constrain development, stress natural resources, and increase competition for water. New agricultural practices will be needed to cope with changing conditions. Less frequent, but more intense, rainfalls could exacerbate flooding.

Each of the hazard profiles now has a 'Climate Change Considerations' subsection that notes where changes in temperature, intensity, hazard distribution, and/or frequency of weather events may increase the probability and vulnerability to hazards in the future, based on a literature review of best available science, e.g. 2014 National Climate Assessment and other studies. Other studies include one from the U.S. Environmental Protection Agency which features a regional study on the effect climate change will have on the Great Plains. "Climate Impacts in the Great Plains" addresses precipitation increases, temperature variations, and impacts on vulnerable communities, impacts on water resources, impacts on agriculture, and impacts on ecosystems. Additional studies are noted within the hazard subsections. Future updates to this plan should continue to integrate the best available science on climate change and how it may alter hazard frequency and intensity.

3.2 PROFILING HAZARDS

44 CFR Part 201 Requirement:

[The State risk assessment shall include an overview of the] location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate…

Hazard profiles include information on past events as well as the probability of future occurrences, expected magnitude and severity of impacts to determine relative levels of risk throughout the state. Information for the hazard profiles and at-risk facilities came from a variety of sources and organizations, including, but not limited to, the following:

- South Dakota Agencies and Departments
  - South Dakota Department of Public Safety
    - Office of Emergency Management
    - Office of Homeland Security
  - South Dakota Department of Environment and Natural Resources
  - South Dakota Department of Agriculture
    - Division of Wildland Fire
  - South Dakota Animal Industry Board
  - South Dakota Department of Health
  - Northern State University, Aberdeen, South Dakota
  - South Dakota State University, Brookings, South Dakota
- Federal Emergency Management Agency
  - FEMA Region VIII
  - HAZUS-MH
- Public Entity Risk Institute
- University of South Carolina Hazards and Vulnerability Research Institute
  - Spatial Hazard Events and Losses Database for the United States (SHELDUS)
  - Social Vulnerability Index for the United States
- National Oceanic and Atmospheric Administration
  - National Climactic Data Center
  - National Weather Service
- U.S. Department of Agriculture Risk Management Agency
- Federal Wildland Fire Occurrence Database
- University of Wisconsin-Madison Spatial Analysis for conservation and Sustainability (SILVIS) Lab
- U.S. Army Corps of Engineers
- U.S. Geological Survey
- Literature and written and oral communications from state and national hazard experts
- Input given at stakeholder meetings during the 2013 update process

2016 Update Highlights

The State Hazard Mitigation Team met twice between June and September 2016 during the course of the HIRA update to discuss the project. Amec Foster Wheeler was the consultant utilized to prepare the update during May-September 2016.

During the 2016 update, all hazard profiles were updated with recent hazard events occurring since the last time the HIRA was updated during 2012-2013. The drought, winter storm, and agricultural disease chapters were enhanced with additional analysis on livestock and crop loss data. Tornado, wind, and winter storm data was obtained and integrated from NCDC database and year of damage dollar losses inflated to 2016 dollars and used to update the vulnerability assessment by county. Building Exposure data utilized in the vulnerability assessment was updated using HAZUS 3.1, which includes inventory data based on 2010 Census data. Updated wildfire occurrence data was obtained from Division of Wildland Fire and the Federal Wildland Fire Occurrence database to update the wildland fire hazard profile. The state has been impacted by several disasters since 2013 including severe flooding, winter storm, and drought. The losses from these disasters have been summarized, including an analysis of the types and amounts of disaster expenditures where available. South Dakota has funded several mitigation projects with FEMA funds. Projects such as power line burial projects have been summarized and compared to high-risk counties for wind, winter storm, and tornado as an indication of progress towards reducing exposure to these hazards and further refinement of vulnerabilities related to Rural Electric Cooperatives. A consequence analysis was completed for each hazard in part to meet Emergency Management Accreditation Program (EMAP) requirements and climate change considerations were added to floods, summer storms, drought, wildfire, windstorm, tornado, and winter storm hazards. Table 3-5 highlights some of the changes made to the hazard identification and risk assessment.

Table 3-5: Summary of Hazard Identification and Risk Assessment 2016 Update Highlights

2016 Hazard Name	Highlights of Changes from previous HIRA
Floods	DFIRM analysis updated, hazard history updated.
Summer Storms	Added as new hazard with a profile on lightning and hail impacts and related vulnerability analysis.
Drought	Incorporated elements of 2015 South Dakota Drought Plan vulnerability assessment.
Wildfire	Incorporated vulnerability analysis from 2015 Drought Plan, new wildland fire occurrence data
Windstorm, Tornado, Winter Storm	Updated with NCDC data; inflated $ losses to 2016; updated tornado probability map. Changed classification scheme for Building Exposure and Population Density to further refine vulnerability by county. Included location of related hazard mitigation projects on maps to indicate loss reduction activities in relation to vulnerable counties. State facilities added to maps to graphically portray potential vulnerabilities.
Hazardous Materials	Added information related to oil and gas development and abandoned mines. Developed additional analysis of risk to state facilities from transportation and Tier II facilities.
Other	Climate change considerations added; EMAP consequence analysis tables added for all hazards; risk summary by hazard developed.

Agricultural Pests and Diseases

Description

Agriculture is South Dakota's prime industry, contributing $20.9 billion dollars to, or 20% of, the state's economy each year. In addition, agriculture and its associated industries employ over 80,000 South Dakotans. According to the most recent (2012) census conducted by the United States Department of Agriculture (USDA), the State had 31,989 farms, with over 43,257,079 acres of farmland, for an average farm size of 1,392 acres; the agriculture industry nets over $2 billion per year in farm income. The state boasts 46,000 producers on 31,700 farms, ninety-eight percent of which are family owned and operated, and over 2,500 farms have been in the same family for more than 100 years. South Dakota's agricultural history dates back to the nineteenth century, when homesteaders used a mule and moldboard plow to break the thick prairie sod. Currently, in the twenty-first century, crop production has increased as farmers embrace new technologies, better hybrids, and more efficient land-use practices. More than 19 million acres of the state is cropland and 23 million acres are devoted to pastureland.

Figure 3-2 South Dakota National Agriculture Rankings by Commodity

U.S. RANK	COMMODITY AND DATE	NUMBER	UNIT	PERCENT OF U.S. TOTAL
1	BISON, inventory, Census of Agriculture, 2012	33,637	head	20.7
	OATS, production, 2014	9,300,000	bushels	13.3
	SUNFLOWER, ALL, production, 2014	876,620,000	pounds	39.6
2	HAY, ALFALFA, inventory, 2014	4,370,000	tons	7.1
	HONEY, production, 2014	24,360,000	pounds	13.7
3	MILLET, PROSO, production, 2014	2,139,000	bushels	15.9
	FLAXSEED, production, 2014	90,000	bushels	1.4
	WHEAT, SPRING, production, 2014	71,680,000	bushels	12.0
4	BEANS, DRY EDIBLE, NAVY , production, 2014	99,000	cwt	2.2
	HAY, ALL, production, 2013	6,665,000	tons	4.8
	WHEAT, ALL, production, 2014	131,260,000	bushels	6.5
5	BEEF COWS, ALL, inventory, January 1, 2015	1,632,000	head	5.5
	CALF CROP, inventory, 2014	1,620,000	head	4.8
	LAMB CROP, inventory, 2014	215,000	head	6.3
	LAND IN FAMRS, 2014	43,300,000	acres	4.7
	POPCORN, production, Census of Agriculture,2012	27,686,379	pounds	3.5
6	BEANS, DRY EDIBLE, CHICKPEAS, production, 2014	37,000	cwt	1.3
	CORN FOR GRAIN, production, 2014	787,360,000	bushels	5.5
	SHEEP AND LAMBS, MARKET, inventory, January 1, 2015	55,000	head	4.1
	SORGHUM FOR GRAIN, production, 2014	9,450,000	bushels	2.2
	SORGHUM FOR SILAGE, production, 2014	220,000	tons	5.3
	WOOL, production, 2014	1,750,000	pounds	6.6
	WHEAT, DURUM, production, 2014	180,000	bushels	0.3
7	CATTLE ON FEED, inventory, January 1, 2015	385,000	head	3.0
	ON FARM GRAIN STORAGE CAPACITY, December 1, 2015	690,000,000	bushels	5.3
	SHEEP AND LAMBS, ALL, inventory, January 1, 2015	255,000	head	4.8
	WHEAT, WINTER, production, 2014	59,400,000	bushels	4.3
8	CATTLE AND CALVES, ALL, inventory, January 1, 2015	3,700,000	head	4.1
	CROPLAND, total, acres, Census of Agriculture, 2012	19,147,320	acres	4.9
	PRINCIPAL CROPS HARVESTED, 2014	17,335,000	acres	5.6
	PRINCIPAL CROPS PLANTED, 2014	17,816,000	acres	5.5
	SOYBEANS, production, 2014	229,950,000	bushels	5.8
	CORN FOR SILAGE, production, 2014	6,200,000	tons	4.8
9	PIG CROP, inventory, 2014	3,684,000	head	3.3
10	HAY, OTHER, production, 2014	2,295,000	tons	2.9
	OFF FARM GRAIN STORAGE CAPACITY, December 1, 2014	345,000,000	bushels	3.2
11	HOGS AND PIGS, ALL, inventory, December 1, 2014	1,250,000	head	1.9
12	CASH RECEIPTS FROM FARM MARKETINGS, 2013	10,352,529,000	dollars	2.6
	BEANS, DRY EDIBLE, ALL, production, 2014	243,000	cwt	0.8
	BEANS, DRY EDIBLE, PINTO, production, 2014	64,000	cwt	0.7

Source: 2015 USDA Agriculture Bulletin No. 75, August 2015

Agricultural hazards are divided into two categories: pests and diseases. For this plan, such events are defined as the naturally occurring infection of crops or livestock with insects, vermin, or diseases that render the crops or livestock unfit for consumption, sale, or other use. South Dakota has a substantial agricultural industry and a significant infrastructure composed of related facilities and locations, so the

potential for infestation of crops or livestock pose a significant risk to the economy of the state. In order to profile each element adequately, this hazard profile focuses on events that primarily affect livestock (primarily disease) and crops (disease and pests). In some cases, pests may also serve as the vector of disease for livestock. For clarity, the profile examines livestock and crop impacts separately, following the same evaluation criteria of location, past events, and probability demonstrated in other profiles.

Small losses caused by agricultural pests and diseases are normal for South Dakota farmers and ranchers. Concerns arise when the level of an infestation escalates suddenly and overwhelms normal control efforts, a new type of infestation occurs, diseases decimate animal populations, or when diseases pose a risk to humans. The levels and types of such events vary based on many factors, including cycles of heavy rains and drought, feeding practices, cross contamination or exposure, or inadequate infection control measures.

While zoonotic diseases (those transmissible to humans from animals or via an animal vector) are a concern, those events are best addressed in a pandemic or contagious disease plan, in order to address the variability and magnitude the events entail. The control of insects and rodents partially addresses the mitigation of Zoonotic disease, but for the purposes of this plan, that is an extra factor, rather than a primary focus. This hazard profile focuses on the diseases which impact the population of domesticated livestock or crops, which in turn damages the economic return on these valuable assets.

The following evaluation of crop hazards is reproduced from the Plant Sciences at South Dakota State website discussing crop production problems:

> Farmers endure a number of problems during the growing season which can curtail yield. Some of these problems occur because best management practices are not applied. The lack of a good stand, crop-nutrient deficiencies, insect infestations, weed population increases, poor field drainage, and salinity problems can to some degree be managed. However, there are some weather related natural events that are beyond the farmer's control. High humidity and strong southerly breezes can carry windborne pathogens from Mexico and the southern states to infect crops. Violent storms from May to August can bring hail can reduce crop yield potential or damage crops beyond recovery. Lack of timely precipitation can wither crops and reduce yields. Late frost in the spring can kill crops and early frost in the fall can curtail the grain filling period of fall harvested crops.[1]

Weeds that infest fields may cause problems during harvest. The weeds may clog small to medium size combines, so alternative harvesting techniques are required. The cut-and-swathing technique is not preferable as it may encourage grain loss and requires a greater investment of time and/or manpower.[2]

Rodent infestations threaten crops, which is one of the primary industries in the planning area. Mice, rabbits, and other pests damage crops in all stages of the production process. Young plants are vulnerable to the rodents who feed on them. Harvested and stored crops may be contaminated by rodents burrowing

[1]http://plantsci.sdstate.edu/woodardh/Soils_and_Ag/Eastern/Crop_Production_Problems/crop_production_problems.htm

[2] http://plantsci.sdstate.edu/woodardh/Soils_and_Ag/Eastern/Crop_Descriptions/crop_desciptions.htm

into storage units, either to feed on the materials or create nests during winter months, or become contaminated by fecal matter. The nature of such infestations makes tracking statistical data nearly impossible. Variables include the geographic distribution of the rodents and the crops, the number of rodents in the area, the presence and proliferation of natural predators, and the reproduction rates relative to the amount of natural food resources available. As such, while this is an acknowledged element of the agricultural hazards, it is not a primary focus in this profile.

Insect plagues also cause significant damage to crops in South Dakota. The last major grasshopper infestation in the United States occurred in the 1930s. Following this disaster, it was decided that local control of grasshopper outbreaks was insufficient and that regional coordination was required. The 1934 Congress charged the U.S. Department of Agriculture (USDA) with controlling grasshoppers on federal rangeland. In 1987, the Animal and Plant Health Inspection Service (APHIS), which is part of the USDA, created the Grasshopper Integrated Pest Management (GHIPM) Project to develop new technologies for managing grasshopper populations. Grasshopper infestations in the 1950s, 1980s, and 2000s further underscore the importance of mitigating this insect-driven hazard.

Similar insect hazards include locusts, aphids, and bark beetle plagues. In 2012, Campbell, Corson, Harding, and Perkins counties all received USDA disaster designations involving insects and disease (S3467). In early March 2010, USDA designated Ziebach County as a primary natural disaster area due to weather and grasshopper problems in 2009.

Location

Since diseases and pests are profiled together, instead of examining each potential hazard individually, the geographic location of the hazards is somewhat general. It is recognized that the individual occurrences of the hazards contained in this profile will exert unequal pressures and impacts. In general, it is important to know where the hazards may occur in order to determine the severity of the hazard when compared to other hazards in this plan. Specific vulnerabilities may be best addressed in county or local mitigation plans.

Livestock diseases are possible anywhere that livestock are present. In addition, humans who come into contact with contaminated livestock or byproducts may also be exposed to livestock diseases. 23,025,294 acres in South Dakota are devoted to pastureland, which accounts for 47.4% of the total land area of the state. Pastureland is primarily located in bands that stretch from north to south in the eastern half of the state, and in the grasslands that dominate the western area of the state. In Figure, pastureland areas are indicated in yellow, while grasslands are indicated in beige.

Similarly, crop diseases are possible in any cultivated cropland environment. While some crop varieties are engineered for resistance to specific diseases or pests, the overall location of any pest or disease hazard corresponds to the cropland extent in the state. Specific variances to general distributions are noted in Table 3-8. 19,095,318 acres in South Dakota are designated as cropland, which accounts for 39.3% of the total land area of the state.

Cultivated crops are more prevalent in the eastern half of the state, though significant areas of cropland interspersed with grasslands also exist in the west. In Figure, these areas are indicated by brown shading.

Rodents such as mice, rats, and rabbits, are found across the entire planning region, as are insects. The presence of the rodents and insects is a consistent feature, with normal population density flows following the seasonal patterns. However, when density of these populations exceeds the capacity of the ecosystem, agricultural industries such as crops and the health of livestock are threatened. As discussed above, the ability to model these trends is difficult and inconsistent.

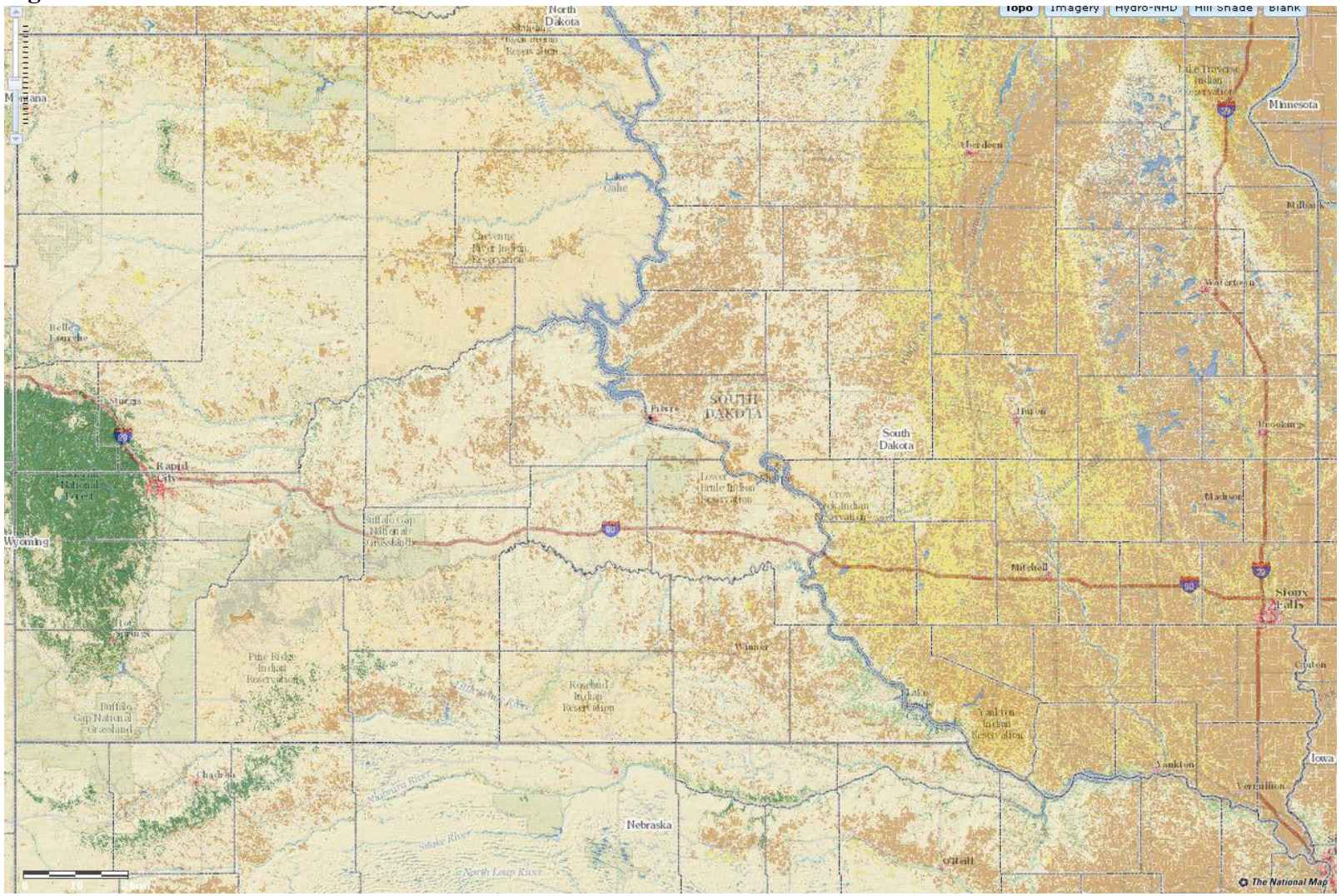
Grasshoppers are a historical insect hazard impacting agricultural production of crops. Figure 3-4 shows the adult grasshopper density for South Dakota measured in September 2012. While the map indicates that the majority of the density ratings are in western South Dakota, outside of the majority of cultivated cropland, this is due to the fact that the USDA does not survey in the eastern part of the State.

The impacts of grasshoppers on cattle have also been significant. Campbell, Corson, Harding, and Perkins counties received USDA disaster designations for losses related to insects and disease (S3467) in 2012. In that same year, 30 counties received a total of $702,633 in indemnities for crop loss related to insects. 22 counties received $184,810 in insect-related indemnities in 2011, and 27 counties received $927,938 in insect-related indemnities in 2010. The crop losses in all three years included forage used to feed livestock. The prediction for 2009, based on the density ratings, indicated that food supplies for cattle in the western portion of the state would be severely impacted by the grasshoppers. This proved accurate in August of 2009, when the Associated Press reported that grasshopper infestations forced ranchers to sell livestock because food supplies were unavailable.[3] South Dakota, specifically Ziebach County, was named in USDA Secretarial Disaster Declaration S2916 for damages done by grasshoppers. **Figure 3-5** predicts the grasshopper hazard for 2016 for the western United States (outbreaks have historically occurred in the 17 states that lie west of the 100th meridian[4]), including South Dakota.

[3] Carson Walker, Associated Press. "Grasshopper Infestation forces livestock sales". http://www.mnn.com/food/farms-gardens/stories/grasshopper-infestation-forces-livestock-sales

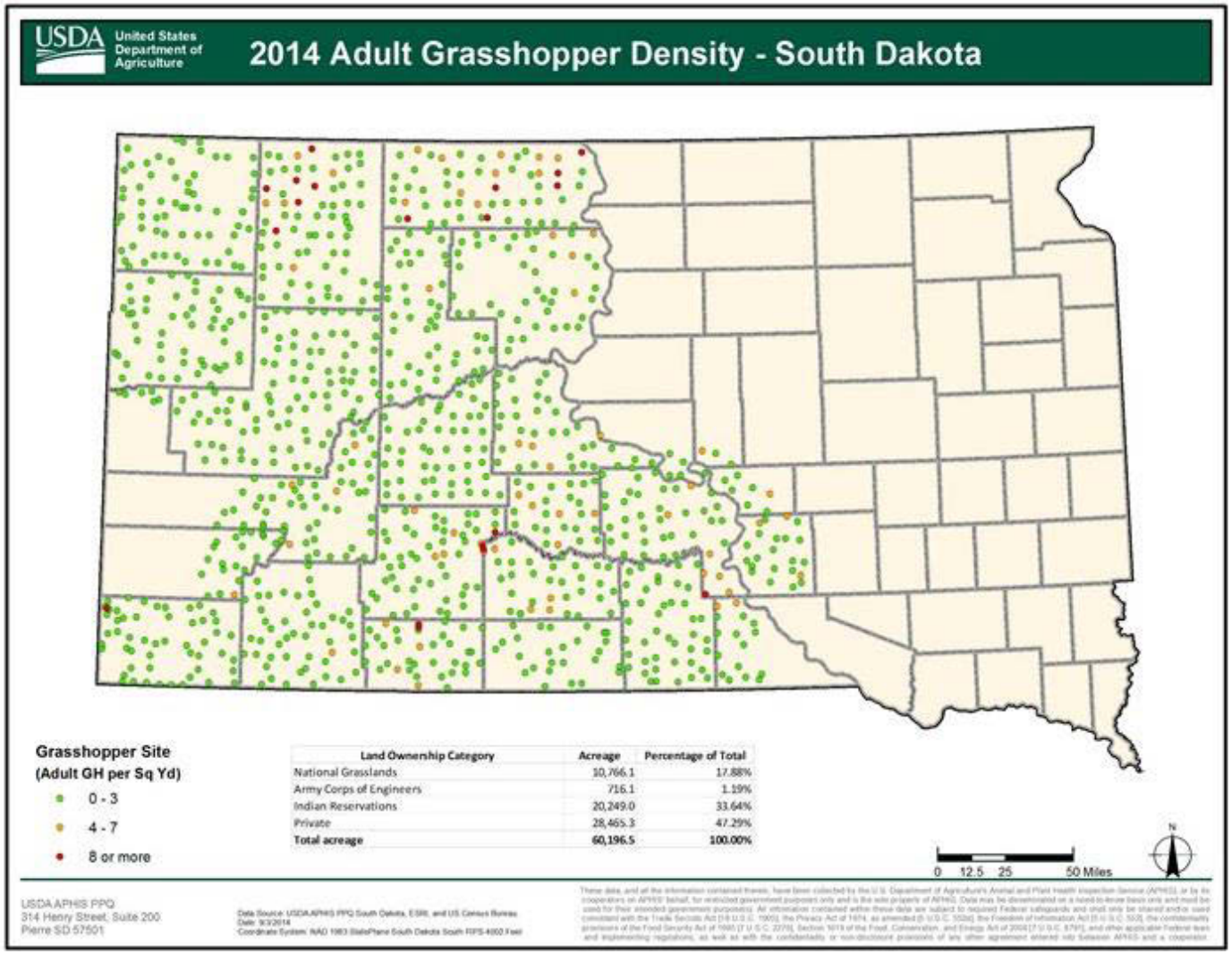
[4] USDA APHIS. http://www.aphis.usda.gov/plant_health/plant_pest_info/grasshopper/index.shtml

Figure 3-3 Land Cover in South Dakota



Source: The National Map Seamless Server hosted by the USGS, using NLCD 2006 Land Cover data.

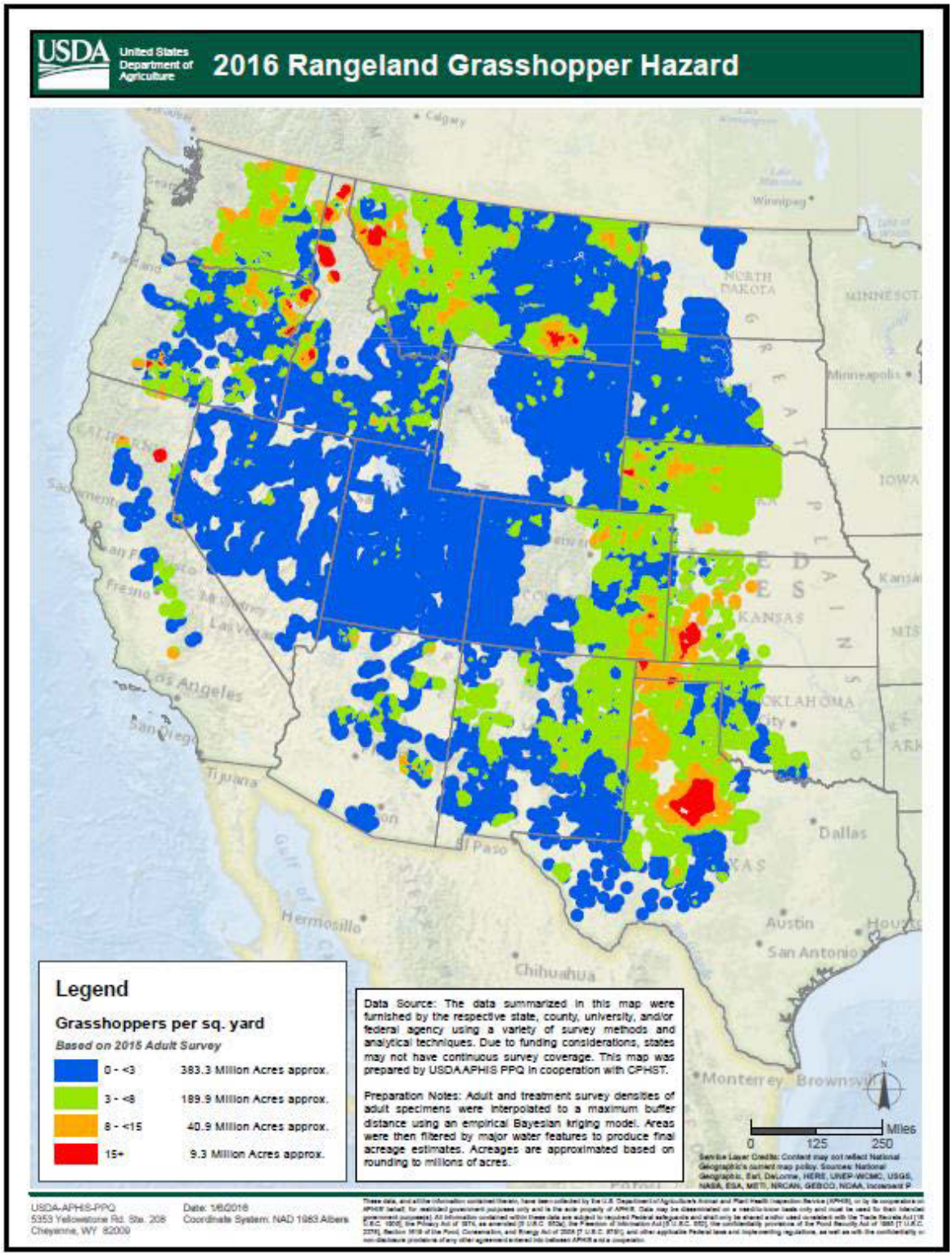
Figure 3-4 2014 Adult Grasshopper Density for South Dakota



Land Ownership Category	Acreage	Percentage of Total
National Grasslands	10,766.1	17.88%
Army Corps of Engineers	716.1	1.19%
Indian Reservations	20,249.0	33.64%
Private	28,465.3	47.29%
Total acreage	**60,196.5**	**100.00%**

Source: USDA, South Dakota Department of Agriculture

Figure 3-5 South Dakota Grasshopper Hazard



Source: USDA APHIS

Past Events

Past events are detailed differently in this section compared to other hazard profiles. While previous occurrences are listed, where applicable, it is also important to recognize the potential devastating diseases or pests for which the State constantly monitors. The use of vaccines (in livestock) and fungicides, pesticides or resistant seeds have mitigated some previously severe hazards. Other potentially devastating hazards have not yet appeared in South Dakota and appropriate preventative measures are in place to help inhibit their introduction. As such, monitored diseases or infestations are as equally important as known events.

Table 3-6 is a summary of the information presented on the South Dakota Animal Industry Board Disease Control Website with additional information provided from the USDA and other resources. Only diseases for cattle, pigs, poultry, and wildlife are profiled here due to their importance to South's Dakota economy. However, additional information on sheep and horses is also available on the website. In addition, diseases with minimal impact on humans and a low incidence rating in animals are not included in this profile.

There are many common crop diseases that impact the production, yield, and overall quality of harvests. Some crops are sold as a commodity, while others are used to support the livestock industry. As with livestock disease, tracking every occurrence is unwieldy because, to some level, crop disease is omnipresent. This section shows the occurrence rate of common crop hazards for the top commodities groups grown in South Dakota - that is, small grains, oilseeds, dry beans and dry peas (ranked 9th in the nation for value of sales), corn for grain (ranked 7th in the nation for production in 2010), soybeans (ranked 8th in the nation for production in 2010), sunflowers (ranked 2nd in the nation for production in 2010), and forage (ranked 3rd in the nation for production). Note that commodities are grouped by disease vulnerability, rather than by commodities group. The information is drawn from an issue of "Extension Extra" published by the College of Agricultural and Biological Sciences at the South Dakota State University, which discusses the recognition and management of common crop diseases in South Dakota.[5] Additional information was obtained from news sources and the USDA for events post-2009.

The 2016 HIRA update did not identify significant events post-2012. Some highlights of the events listed below, or events of particular significance, include:

- Campbell, Corson, Harding, and Perkins counties received USDA disaster designations for losses related to insects and disease (S3467) in 2012. In that same year, 30 counties received a total of $702,633 in indemnities for crop loss related to insects. 22 counties received $184,810 in insect-related indemnities in 2011, and 27 counties received $927,938 in insect-related indemnities in 2010. The crop losses in all three years included forage used to feed livestock.
- In 2013, the majority of counties in the State were declared by the USDA for drought (S3591; S3620; S3505; S3522; S3549); secondary impacts of this drought included insect infestation and disease spread.
- Several counties also received indemnities for crop losses related to plant disease between 2010 and 2012. 12 counties received $62,183 in 2012, 38 counties received $3,303,117 in 2011, and 16

[5] http://sdces.sdstate.edu/ces_website/hit_counter.cfm?item=ExEx8005&id=1246

counties received $572,831 in 2010. Impacted crops included wheat, corn, soybeans, oats, dry peas, sunflowers, forage, and "other" not specified. The specific plant diseases that caused these losses were not identified in the Risk Management Agency data.

- The USDA produced a "Cattle Death Loss" report in 2011 which detailed the number of cattle and calves lost to various causes (predator and non-predator) in each state in 2010. A total of 68,000 head of cattle and 90,000 calves died in South Dakota in 2010. 12.6% (8,568 head) of cattle losses were attributed to digestive problems, 31.1% (21,148 head) to respiratory problems, and 5.2% (3,536 head) to other unspecified diseases. 12.8% (11,520 head) of calf losses were related to digestive problems, 29.2% (26,280 head) to respiratory problems, and 0.9% (810) to other unspecified diseases. Additional details were not available on the specific nature of the digestive and respiratory problems. At a value of $1,133 per head for cattle and $381 per head for calves, South Dakota's cattle industry losses in 2010 totaled $52,384,926 due to respiratory, digestive, and other diseases. (Weather-related cattle and calf losses are discussed in the *Winter Storm* hazard profile.)
- The USDA "Cattle Death Loss" report comes out approximately every five years, but previous reports for 2005 and 2000 organized data by region rather than state. The 1995 and 1991 reports are organized by state and can be compared to the 2011 report. The 1995 report indicates that a total of 59,600 cattle and 162,600 calves were lost in 1995. Of the 59,600 total cattle deaths, 6,800 were lost to digestive problems and 14,300 to respiratory problems. Of the 162,600 total calf deaths, 37,000 died from digestive problems and 30,000 were lost to respiratory problems. In 1991, cattle and calf losses totaled 55,000 head and 110,000 head respectively. Digestive problems killed 8,100 cattle and 33,400 calves. Respiratory problems killed 16,500 cattle and 31,300 calves. "Other diseases" was not listed as a category in 1995 or 1991. Total dollar value per head was not provided in the 1995 and 1991 reports.
- In January 2011, the USDA designated Jackson and Todd counties as natural disaster areas due to the ongoing grasshopper infestation that began in June 2010. Designated contiguous counties included Bennett, Jones, Pennington, Tripp, Haakon, Mellette, and Oglala Lakota (previously Shannon County).
- In April 2010, the State was approved for pasture grazing loss assistance under the Emergency Livestock Assistance Program (ELAP) due to the 2009 grasshopper infestation.
- In 2009, the State experienced combined effects of severe storms with hail, high wind, flooding, and grasshopper infestation in 35 counties. This led to the release of USDA Secretarial Disaster S2916.
- In 2005, the state experienced an unusually high outbreak of anthrax, with 56 positively confirmed cases in 18 counties.
- Trichomoniasis (trich) cases have been steadily increasing in recent years. The highest number of cases also occurred in FY 2005, with 45 positive cases in 11 counties.
- Asian soybean rust is still not documented and confirmed in the state, but extensive scouting efforts are underway, particularly in the southeast counties.
- The 2016 HIRA update did not note any significant agricultural pest and/or disease events past 2009.

Table 3-6 South Dakota Livestock Diseases

Disease Name	Incidents, history, and other reporting measures	Human Vulnerability
Cattle		
Brucellosis, also known as Bangs Disease or Bangs	U.S. states are free from Brucellosis in domestic cattle herds due to extensive vaccination and testing requirements. Buffalo and Elk in the Greater Yellowstone Area remain natural carriers of the disease and present the largest risk to domestic cattle herds. Documented cases include far-reaching impacts and tremendous costs for movement restrictions, testing requirements, indemnities, and epidemiology.	Yes, if ingested or directly exposed to the bacteria. Human-to-human transmission is possible, but rare.
Tuberculosis, also known as TB.	South Dakota has maintained a "TB Free" status by the USDA since 1982; however, all intact dairy cattle imported to the state must reflect a 'negative' result in official TB testing within 60 days prior to entering South Dakota. The bovine strain of bacteria is distinct from the most common forms that impact humans. However, the strain may be passed between cattle, from humans to cattle, and from cattle to humans. In both human and cattle patients, TB may be fatal if untreated or neglected.	Yes, if ingested (particularly from untreated milk). Sustained animal-to-human transmission is possible but rare.
Bovine Spongiform Encephalopathy (BSE), also called 'Mad Cow Disease'	First surfacing in Great Britain in 1986, BSE is a chronic degenerative disease of the central nervous system. There is no method for testing for the disease in live cattle, so suspected cases pose an extreme cost impact on ranchers. There have been sporadic cases in Canada and the United States. Strict regulations prohibit the feeding of ruminant derived proteins to ruminants. The disease is not passed between cows except via consumption. According to the Center for Disease Control, the first confirmed domestic case of BSE disease was reported in Washington state in 2003. Two subsequent diagnoses were confirmed for a 2004 case in Texas (confirmed in 2005) and in 2006 in Alabama. Luckily, these cases have resulted in minimal impact on domestic cattle herds, but monitoring remains a key component.	Suspected yes, if ingested. The link is suspected between VSE and certain cases of CJD, which is a chronic degenerative central nervous disease in humans.
Anthrax	Anthrax is a spore-forming bacterium that causes acute infections. In 2005, South Dakota experienced a serious anthrax outbreak, with 55 herds with confirmed losses to the disease in the space of four months. Mitigation and response measures helped contain the outbreak, with efforts to vaccinate over 1 million cattle during the summer months. The State Veterinarian reported that the effects of drought, contributed to the severity of the 2005 outbreak. Since South Dakota is located in the 'anthrax belt', potential losses and vulnerability remain high and vigilance remains critical. Previous cases include 1infected herd in 2009, 3 in 2008, 2 in 2007, and 2 in 2006.	Yes, if spores are inhaled, ingested, or infected materials are improperly handled. The disease is not known to be peer-to-peer transmissible.

Disease Name	Incidents, history, and other reporting measures	Human Vulnerability
Johne's Disease (pronounced Yo-nees), also called Paratuberculosis	Johne's disease is a chronic infection that causes diarrhea and wasting, which primarily impacts cattle over the age of 2 years, and is also found in other ruminant animals such as goats and sheep. The disease is closely related to tuberculosis, but grows very slowly. The disease causes wasting of the inflicted animals and may be spread via fecal matter, nursing from infected dams or contamination of the udder with manure, or en vitro. The disease may cause early death or culling losses, decreased milk production, decreased slaughter weights, loss of show, sale and breeding animals, and incurred veterinary costs. There is no effective vaccine. Johne's disease cases are reported at a rate of approximately 4.4% and appear to be increasing. Dairy cows seem to demonstrate a higher occurrence rate than beef cows.	There does not appear to be a transmission of this disease to people. Crohn's disease is a similar infliction in human populations.
Foot and Mouth Disease (FMD)	FMD is a fast-spreading virus which impacts all cloven-footed animals and causes blisters on feet, in mouths, and on mammary glands, resulting in lameness, the inability to eat or drink, and mastitis in dairy animals. In all cases, animals rapidly lose weight and may die. Transmission rates are nearly 100% of exposure, and young animals may die. FMD poses huge economic risks to livestock owners and consumers. In February 2001, the UK was forced to destroy over 9% of the national food animal production industry, and over 11 months to eradicate the disease.	FMD is distinct from Hand, foot, and mouth disease that impacts humans though the symptoms are similar. People cannot contract FMD.
Vesicular Stomatitis (VS)	VS is a virus that causes similar symptoms as FMD and is highly contagious, though it demonstrates a lower mortality rate. The disease may lead to serious restrictions on the movement, marketing, and exportation of animals from affected areas, which has a significant economic impact on livestock-driven economies. While no cases have been diagnosed recently in South Dakota, cases in nearby states underscore the need for vigilance and close reporting requirements.	Humans may contract the disease from sand flies or improper handling of infected animals and animal byproducts. Symptoms are flulike.
Trichomoniasis, also called 'trich'	Trich is a venereal disease that causes infertility and occasional abortions in cows. Bulls, once infected, carry the disease for life but cows seem to spontaneously recover after a period of infection, in some cases. During the FY 2005 breeding season, South Dakota experienced an unexpected resurgence of the disease in 45 confirmed cases, all west of the Missouri river. The known endemic qualities of the disease and the presence of the disease in states west and south of South Dakota, increased cases and magnified losses. Regulations for controlling and reporting Trichomoniasis were effected on June 1, 2005. Additional cases include 13 in FY 2009, 7 in FY 2008, 10 in FY 2007, and 9 in FY 2006.	Humans may contract the disease and spread it from person to person via sexual contact. The disease may be contracted from livestock through improper hygiene when handling infected animals.
Swine		

Disease Name	Incidents, history, and other reporting measures	Human Vulnerability
Psuedorabies (PRV), also known as Aujesky's Disease or mad itch in cattle.	PRV is a viral disease that causes abortion, high mortality of piglets, and may cause other symptoms in adult pigs. In addition, cattle, dogs, bears, cats, sheep, rabbits, and raccoons may contract the disease, which often proves fatal in these secondary hosts. The disease is spread via nasal secretions and saliva. On April 16, 2003, South Dakota was granted Stage V-Free status. Though domestic swine herds have been PRV-free since 2003, the disease remains in feral herds, which pose the greatest risk to domesticated animals. Positive animals must be destroyed to limit the spread and in some cases the entire herd must be destroyed. The disease is considered one of the most economically devastating diseases of swine herds and the potential for a reintroduction of the virus from feral pig exposures remains a concern.	Humans are not potential hosts.
Porcine Reproductive and Respiratory Syndrome (PRRS)	PRRS is a virus that attacks the respiratory system and leads to an overall weakened immune system. The disease is highly contagious and spreads rapidly, but seems to impact different herds with varying degrees of severity for unknown reasons. First identified in the U.S. in North Carolina in the 1980s, the disease spread rapidly across the continent. All breeds and ages of pigs are susceptible, though there is some indication that some breeds demonstrate less vulnerability than others. The impacts of this disease are still under evaluation, but losses to pig herds have economic ramifications for sale for slaughter and breeding.	There is no known human susceptibility to the disease. Humans may serve as mechanical vectors of the disease without proper infection control practices.
Poultry		
Avian Influenza	While Avian Influenza is not currently documented in the state, the concern remains that exposure could result in the infection of domestic avian flocks, including turkeys, geese, chicken, and other fowls, that may contribute to the crossover between birds and people. A detailed response and containment plan has been developed and is a factor in mitigation should quarantine and/or subsequent destruction of flocks be required. A surveillance project went into effect in FY 2007.	Currently humans may contract the disease through extensive exposure to avian carriers. The concern is that the influenza serotype could genetically alter to sustain peer-to-peer transmission.
West Nile Virus	The first identified domesticated cases of WNV occurred in FY 2006, identified in geese at a production site in northeastern South Dakota.	Though mosquitoes remain the primary vector for human transmission, close contact with birds also increases the risk of exposure and may contribute to an alteration of the virus for sustained peer-to-peer transmission.
Wildlife		
Chronic Wasting Disease	The first case of CWD in farmed elk or deer in the U.S. was identified in a private South Dakota herd in late 1997. On February 5, 1998, a mandatory Cervid Chronic Wasting Disease Surveillance Identification (CCWDSI) Program was enacted. This monitoring program has become the model program for numerous other state CWD monitoring programs as well as the federal interim CWD monitoring plan.	No known human transmissions exist at this time. The disease is a variant of the same family that houses BSE, however, so appropriate precautions are appropriate.

Disease Name	Incidents, history, and other reporting measures	Human Vulnerability
Rabies	Rabies in the wildlife population remains at a high level. Skunks are the reservoir of the disease and they represent the largest number of positive diagnoses at the laboratory. Bats have also been recognized as a significant reservoir of rabies. For FY 2009, thirty-two (32) animals were reported infected with rabies, compared to twenty-nine (29) in FY 2008, twenty-five (25) in FY 2007; fifty-three (53) in FY 2006; eighty (80) in FY 2005; one hundred five (105) in FY 2004.	Yes, if exposed through bites or handling of infected animals.

Sources: South Dakota Animal Industry Board Disease Control Website, Centers for Disease Control, U.S. APHIS

Table 3-7 Small Grains

Disease	Winter Wheat	Spring Wheat	Barley	Oats	Rye	Occurrence
Barley Yellow Dwarf (Red Leaf of Oats)	X	X	X	X		Common
Common Root Rot	X	X	X	X	X	Widespread
Covered Smut & Common Bunt	X	X	X	X	X	Fairly Common
Dryland Root & Crown Rot	X	X	X	X	X	Widespread, most serious on winter wheat
Leaf Rust	X	X	X	X		Widespread
Loose Smut	X	X	X	X		Common (>2% In Given Field)
Scab (Fusarium Head Blight)	X	X	X	X	X	East River Counties: Common West River Counties: Rare
Stem Rust	X	X	X	X	X	Rare
Stripe Rust	X	X				Frequent, Severity Varies By Year
Take All	X					Rare
Tan Spot, Septoria Leaf Blotch & Other Leaf Spot Diseases	X	X	X	X		Widespread
Vomitoxin	X	X	X	X	X	Fairly Common
Wheat Streak Mosaic	X	X				Frequent

Table 3-8 Sunflowers, Oilseeds, Dry Beans, Dry Peas and Soybeans, Corn, Alfalfa and Flax

Disease	Sun-flowers	Canola	Safflower	Field Pea	Chick-pea	Lentil	Dry Bean	Soy-beans	Corn	Alfalfa	Flax	Occurrence
Alternaria Leaf &Stem Spot, Leaf Blight	X		X*									Annually in late summer *common
Anthracnose						X	X		X*	X	X*	Rare *Occasional
Apical Chlorosis	X											Infrequent
Ascochyta Blight					X	X						Common
Asian Soybean Rust								X				Not yet reported in the state
Aster Yellows		X									X	Infrequent, no control
Bacterial Blight & Wilt$				X			X*	X		X$		Widespread, *Occasional $Rare
Bean Pod Mottle								X				Widespread
Black Leg		X										Common
Blackspot		X										Common, no control
Brown Spot								X				Widespread
Brown Stem Rot (BSR)								X				Occasional
Charcoal Rot								X				Occasional, extreme southeast counties
Common Leaf Spot										X		Common
Damping-Off			X						X	X		Common
Downy Mildew	X							X				Common
Eyespot									X			Occasional
Frogeye Leaf Spot								X				Rare in state, observed in extreme southeast counties
Fusarium Root Rot and Wilt$				X	X	X	X	X		X$*	X$*	Occasional *Common
Goss's Bacterial Wilt & Blight									X			Rare
Gray Leaf Spot									X			Fairly common

Disease	Sun-flowers	Canola	Safflower	Field Pea	Chick-pea	Lentil	Dry Bean	Soy-beans	Corn	Alfalfa	Flax	Occurrence
Holcus Spot									X			Annual in early summer
Maize Dwarf Mosaic									X			Common, typically low incidence
Northern Stem Canker								X				Frequent
Nothern Corn Leaf Blight									X			Occasional
Pasmo											X	Occasional
Phoma Black Stem	X											Annually in late summer
Phomopsis Stem Canker	X											Annually in late summer
Pod & Stem Blight								X				Widespread
Pythium Damping Off & Seed Decay				X	X	X	X	X		X		Widespread
Pytophthora Root & Stem Rot								X		X*		Widespread *Fairly Common
Rhizoctonia Seedling Blight[$] & Root Rot								X			X[$]*	Widespread *Common
Root & Crown Rot Complex										X		Common
Sclerotinia Wilt, Stalk Rot & Head Rot	X											Annually in late summer
Soybean Cyst Nematode								X				Widespread in south-eastern counties, scattered in other areas
Soybean Mosaic								X				Rare
Spring Black Stem & Leaf Spot										X		Widespread
Stalk Rot Complex									X			Annual in fall
Stem Nematode										X		Rare, restricted to western counties
Sudden death syndrome (SDS)								X				Rare: only in Clay County

Disease	Sun-flowers	Canola	Safflower	Field Pea	Chick-pea	Lentil	Dry Bean	Soy-beans	Corn	Alfalfa	Flax	Occurrence
Summer Black Stem & Leaf Spot										X		Common
Verticillium Wilt										X		Common
White Mold		X	X	X	X	X	X					Common

Probability

To some extent, the probability of these events is guaranteed on an annual basis, particularly when evaluated on a statewide scale. The determination of probability becomes most valuable when areas of particular occurrence rates, or when events of unusual severity, are recorded. Many times, extreme events are documented concurrently with other hazard event occurrences, such as the outbreak of high anthrax levels in 2005, which was attributed to drought; the grasshopper plagues of the 1930s, also attributed to drought; or the recurrence of certain crop molds, which correspond to unusually wet growing periods.

Overall, if the general annual probability of occurrence statewide is near 100%, some general probabilities for regions or specific counties may also be drawn.

In general, the western portion of the state (counties lying to the west of the Missouri River) have a higher documented occurrence rate of trich and stem nematode afflictions of alfalfa crops. Counties along the river basins bore the brunt of the anthrax outbreaks in 2005. Eastern counties have higher documented rates of the soybean cyst nematode, frogeye leaf spot, scab, and West Nile Virus in domestic fowl flocks. Areas with a primarily cultivated crop land use are more susceptible to crop diseases, and thus have a predicted higher probability rating than areas devoted to rangeland. Areas where wildlife interaction is more common among livestock have higher exposure probabilities to diseases like rabies and brucellosis.

A South Dakota State University Extension entomologist said that "based on the high grasshopper count late last summer (2009), there is potential for another year of grasshopper infestation in counties in western South Dakota" This prediction was accurate; grasshopper infestations continued to plague South Dakota in 2010. Dangerously high levels of grasshopper populations seem to follow a cycle of 7 to 10 years, meaning the state can reasonably expect another between 2017 and 2020. Drought or periods of higher-than-average temperatures, particularly in the winter, increase the severity of grasshopper population numbers, because more eggs survive to hatch. Based on historical data, South Dakota has experienced four grasshopper plagues in 123 years (1887 to 2010) for an annual chance of 3.2%. Smaller infestations, which still exert significant economic impact, may be predicted at the cycle of ten years, or a 10% annual chance.

Climate Change Consideration

With agriculture as South Dakota's primary industry, climate change has the potential to have a direct impact on the economy. UC Davis published research on the effects climate change has on agricultural pests, crop diseases and weed species. Climate change can alter and increase the range or "damage niche" of many weed species. With these geographic range shifts, new weed species can enter communities further north than in the past. The effects of climate change on vary by region and crop type, so it is important to understand the different environmental factors and the underlying physiological mechanisms' responses. If the invasion of new species can be detected in advance, efforts can be made to control the growth.

Crop diseases can be animal, fungal, bacterial or viral. An increase in severe weather events such as tornadoes, high wind, or storms may catalyze the spread of crop disease such as soybean rust. Local increases in precipitation also have the potential to aid in the dispersal of plant and crop disease.

Various frost-sensitive insects have been shown to increase in population with the rise of milder winters. Increasing temperatures also aid in the growth and reproduction in certain insects. Studies on aphids and moths have shown that increasing temperatures can allow insects to reach their minimum flight temperature sooner, aiding in increased dispersal capabilities. Multiple studies have shown the northward expansion or shift of insect ranges, such as Edith's checkerspot butterfly or the mountain pine beetle, to be correlated with increasing temperatures.

The National Climate Assessment explains that climate change has both positive and negative consequences to agricultural productivity. Winter and spring precipitation is expected to increase, which may increase soil moisture reserves during the early season, but may also be offset by fields too wet to plant. Warmer winters may foster an environment that allow for pests and invasive weeds to survive through the season.

Flood

Description

Throughout the United States, flooding is recognized as the most prominent disaster-producing phenomenon, generating annual losses in the billions of dollars. Floods are among the most serious, devastating, and costly natural hazards that affect South Dakota. The greatest impact of these phenomena has been to the eastern half of the state, principally, the Big Sioux, Vermillion, and James River basins, which have recurring problems.

The following is extracted from "Flooding in South Dakota," a fact sheet written by Stan F. Pence from the South Dakota Department of Environment and Natural Resources.

> **What Is a Flood?**
> A flood occurs when water rises to flow over land that is normally dry. Floods happen in low-lying areas, such as valley bottoms, lake basins, and coastal areas. In South Dakota, flooding occurs mainly in valley bottoms, deep canyons, and lake basins when the amount of water moving through a river, or entering a lake, is so great that the natural or artificial banks can no longer contain all of the water. Therefore, the water overflows the banks of the river or lake and spreads out onto low-lying areas that are not normally covered with water.
>
> **What Causes A Flood?**
> In South Dakota, there are two main climatological causes of flooding: runoff from rainfall and runoff from melting snow. The water from rainfall or melting snow flows overland until it reaches a nearby river or lake. If the river or lake cannot hold all of the water that is entering it, some of the water will begin to overflow the banks of the river or lake, causing flooding. The size of the flood is commonly influenced by such factors as the intensity of the rainfall, length of the rainfall, melting rate of the snow, and the infiltration rate of the water into the ground.
>
> In addition to climatological reasons for flooding in South Dakota, floods can also result from the failure of dams. Dam failure can result from defective construction, poor maintenance or a poor

foundation. Many small dams in South Dakota fail because their spillway is not big enough. Often, failure occurs as a result of extremely heavy rainfall that causes a large increase in the amount of water held by the dam. This increase in water behind the dam could place more stress (pressure) on the dam than it was designed to handle, causing the dam to fail.

What Types of Floods Occur in South Dakota?

Four types of floods can occur in South Dakota. The first type is commonly called a flash flood. A flash flood is the result of several inches or more of rain falling in a very short period of time, often tens of minutes. This high intensity rainfall is commonly caused by powerful thunderstorms that cover a small geographic area. Because so much water is falling onto the ground very rapidly, there is little time for the water to soak in, and most of the water runs off into nearby rivers or lakes. The flood that occurs as a result of this runoff happens very rapidly, hence the term “flash.” This type of flood is generally very destructive, affecting a fairly small, localized area, commonly several tens of square miles or less. The flash flood often ends almost as quickly as it started. Probably the best-known flash flood in South Dakota occurred when Rapid Creek left its banks on June 9, 1972, in Rapid City. Fifteen inches of rain that fell in less than 6 hours caused the flooding. This flood was devastating both in terms of loss of human life and property damage. Two hundred thirty-eight people lost their lives in this flood and about $150 million (in 1972 dollars) of property damage occurred.

The second type of flooding is sometimes termed the long-rain flood, and is the most common cause of major flooding. This type of flood results after several days or even weeks of fairly low-intensity rainfall over a widespread area, often hundreds of square miles. As a result, the ground becomes "water logged," and the water can no longer infiltrate into the ground; therefore, the water begins to flow toward rivers or lakes. The flooding that can result is often widespread, covering hundreds of square miles, and can last for several days or many weeks. Much of the flooding that occurred in eastern South Dakota during the summer of 1993 was this type of flooding.

The third type of flood in South Dakota is the result of melting snow in the spring. This type has characteristics that are almost a combination of the flash flood and long-rain flood. The area covered by this type of flood is generally not as large as that covered by the long-rain flood, but is typically larger than that covered by the flash flood. Generally, the flood lasts for several days, occurring when large amounts of snow melt rapidly due to warm temperatures. The flooding can be made worse if the ground remains frozen while the snow is melting; this causes all of the melt water to run off to nearby rivers and lakes rather than infiltrate into the ground.

Some of the largest floods that have occurred in South Dakota were the result of melting snow and ice. These large floods have occurred along the entire length of the Missouri River. The Great Flood of 1881 is probably the most well-known of all the floods to take place in South Dakota. Ice jams on the river caused the flooding to become extremely devastating, destroying large amounts of property and causing many lives to be lost. Towns such as Yankton, Vermillion, Burbank, Meckling, and Pierre were all severely damaged by the flooding.

The fourth type of flood results from the failure of dams or levees. The four largest dams in South Dakota—Oahe at Pierre, Big Bend at Fort Thompson, Fort Randall at Pickstown, and Gavins Point at Yankton—are all located on the Missouri River. Large dams in the Black Hills are the Deerfield, Pactola, Sheridan, and Angostura dams. If any of these large dams were to fail, flood damage

could be very great. Fortunately, all of these dams are considered to be properly constructed and have been designed to hold back very large amounts of water; therefore, they are considered to be very safe, and the likelihood of failure is extremely small. Except for these Missouri and Black Hills dams, the majority of the dams in South Dakota are very small, and if they were to fail, flooding would likely be minimal. Levees protect many areas in South Dakota; however, many of these levees protect small areas from flooding (see Figure 3-8).

Further information regarding dam and levee failure and other flooding risk in South Dakota follows.

Dam Failure

South Dakota has approximately 2,500 dams in the National Inventory of Dams (see Figure 3-7 in Location section below). The state defines a dam as follows: "a structure is a dam if the height to the dam crest is greater than or equal to 25 feet and the storage at the dam crest (not at the spillway elevation) is greater than 15 acre feet or if the height to the dam crest is greater than 6 feet and the storage at the dam crest (not at the spillway elevation) is greater than or equal to 50 acre feet. The height of the dam is the difference in elevation between the natural bed of the watercourse or the lowest point on the toe of the dam, whichever is lower, and the crest elevation of the dam."

Of the roughly 2,500 dams, 89 are high hazard dams. Eighty five of these high hazard dams, of which 73 are state regulated, have emergency action plans. This is an improvement since 2007, when 21 dams had no emergency action plan and in 2012, 15 had no emergency action plans. All high hazard dams are required to have emergency action plans. Of the total dams, approximately 155 are significant hazard dams. Because of South Dakota's low population and low density, most of the state's dams are low hazard dams. In *Federal Guidelines for Dam Safety: Hazard Potential Classification Systems for Dams* (FEMA 2004), dams are classified as follows:

- **Low Hazard Potential**—Dams assigned the low hazard potential classification are those where failure or mis-operation result in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner's property.
- **Significant Hazard Potential**—Dams assigned the significant hazard potential classification are those dams where failure or mis-operation result in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.
- **High Hazard Potential**—Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life as well as economic, environmental, and lifeline losses.

Levee Failure

In addition to these dams, South Dakota also has levees that pose flood risks. Levees are earth embankments constructed along rivers and coastlines to protect adjacent lands from flooding. Floodwalls are concrete structures, often components of levee systems, designed for urban areas where there is insufficient room for earthen levees. When levees and floodwalls and their appurtenant structures are

stressed beyond their capabilities to withstand floods, levee failure can result in loss of life and injuries as well as damages to property, the environment, and the economy. In South Dakota, there are numerous levees ranging from small agricultural levees that protect farmland from high-frequency flooding to large urban levees that protect people and property from larger-less frequent flooding events such as the 100-year and 500-year flood levels. For purposes of this discussion, levee failure will refer to both overtopping and breach of a levee as defined in the FEMA's Publication —*So You Live Behind a Levee* (http://content.asce.org/ASCELeveeGuide.html).

- **Overtopping** occurs when floodwaters exceed the height of a levee and flow over its crown. As the water passes over the top, it may erode the levee, worsening the flooding and potentially causing an opening, or breach, in the levee.
- **Breaching** - A levee breach occurs when part of a levee gives way, creating an opening through which floodwaters may pass. A breach may occur gradually or suddenly. The most dangerous breaches happen quickly during periods of high water. The resulting torrent can quickly swamp a large area behind the failed levee with little or no warning.

Location

According to the National Oceanic and Atmospheric Administration National Weather Service, flash floods are the deadliest natural disaster in South Dakota. They are caused by stationary or slow-moving thunderstorms that produce heavy rain over a small area. The Black Hills are especially vulnerable to flash floods, where steep terrain and narrow canyons can funnel heavy rain into small creeks and dry ravines, turning them into raging walls of water. Even on the prairie, normally dry draws and low spots can fill with rushing water during very heavy rain.

Critical to the mission of disaster identification and risk assessment is the ability to statistically log and compare various types of flood and demographic data. Through the use of modern GIS technologies, multiple analyses of structures, historical sites, city boundaries, airports, and schools can be performed and then compared to the floodplains in which they are located. Based on numbers of people and property at risk, i.e., the vulnerability of people and property at risk, the South Dakota Office of Emergency Management has determined that the cities of Aberdeen, Pierre, Rapid City, Sioux Falls, and Watertown are at the greatest risk from flood events.

South Dakota is divided into 14 river drainage basins (See Figure 3-6). These basins extend beyond the political boundary of the state. Although not discussed or included in this plan, an interstate understanding of water policy is required to fully analyze and comprehend South Dakota water systems.

Figure 3-6: Drainage Basins of South Dakota

Source: USDA Natural Conservation Resources Service South Dakota (www.sdconservation.org/files/SDWatershedsQ.pdf)

Missouri River Basin

The following description of the Missouri River Basin is from Microsoft Encarta Online Encyclopedia:

> Considered as a separate river, the Missouri is the longest in the United States. In combination with the Mississippi River into which it flows at St. Louis, it is the longest river system in the United States. The river begins where the Gallatin River, Jefferson River, and Madison River come together in the foothills of the Rockies in Montana. It flows through Montana, North Dakota, and South Dakota before forming the boundary between Iowa and Nebraska. It forms the extreme northeast border of Kansas before turning almost due east through the state of Missouri.
>
> South Dakota is drained almost entirely by the Missouri River and its tributaries. The only sections that are not lie in the extreme northeast and northwest. The Missouri flows southward and then southeastward across the state, in a deep, wide channel. It forms part of the South Dakota–Nebraska state line. Much of the South Dakota section of the river is now made up of a chain of four reservoirs impounded by large dams. These dams include Fort Randall, Gavins Point, Big Bend, and Oahe dams which were built for flood control and to provide water for irrigation and the generation of hydroelectricity. Lake Oahe is formed by Oahe Dam at Pierre. The James River, the Vermillion River, and the Big Sioux River, all in the eastern half of the state, flow southward in roughly parallel

courses to join the Missouri. In the western part of the state the Grand, Moreau, Cheyenne, Bad, and White rivers flow generally eastward to join the Missouri.

South Dakota cities on the river include Pierre, Mobridge, Oacoma, Chamberlain, Pickstown, Fort Thompson, Ft. Pierre, Springfield, Yankton, and Lower Brule. The interstate effects of water policy are evident in the capital city of Pierre, where national policy objectives produce an ever-rising Missouri River to offset flooding in downriver states.

The largest natural lake in South Dakota is Lake Thompson in the east-central part of the state. Other natural lakes of significant size in South Dakota are lakes Traverse and Big Stone, both in the northeastern corner of the state. Lake Traverse is a reservoir created by damming up the Boise Des Sioux Rivers near Rosholt. Big Stone Lake is a reservoir created by damming the Little Minnesota River near Big Stone City. In addition, there is the Waubay Lakes Chain and adjoining closed basins (discussed further in this section) located in the northeastern part of the state, which have continuous ongoing flooding issues. Numerous small lakes and sloughs dot the landscape of northeastern South Dakota, as well. The largest lakes are the reservoirs behind dams on the Missouri River, all of which were constructed as part of the Missouri River Basin Project.

Big Sioux River Basin

The Big Sioux River Basin is the eastern most major river pattern in South Dakota. It is formed within a topographic feature known as the Coteau de Prairie Highlands. This glacial formed feature rises about 800 feet above the bordering Red River lowlands of Minnesota. It is also bordered on the west by the James River lowland. The Coteau has what is known as a flatiron shape lying in a general northwest to southeast direction. It is about 200 miles long and 80 miles wide at the widest point. It has a variation in elevation from 2,050 feet at the highest point to 1,090 feet at the lowest point.

The northern part of the Coteau has geologically developed features of potholes, sloughs, and lakes. During periods of low precipitation, these features tend to hold backwater and do not contribute to the drainage of the Big Sioux River. Conversely, during wet years, this area can accumulate enough moisture to greatly increase the water supply to the drainage basin. There are about 1,970 square miles of land within the basin that is designated as noncontributing to the drainage system. The portion of the basin that does contribute to the Big Sioux River is about 7,280 square miles. A total of 4,280 square miles of the figure is located in South Dakota

The headwaters for the Big Sioux River are found in the Coteau Lake Region of Roberts and Day counties. The river flows in a southerly direction to its junction with the Missouri River near Sioux City, Iowa. The variation in elevation from the headwaters to the mouth greatly influences the movement of water through the basin. The elevation decreases from 1,826 feet near Waubay to 1,281 at Sioux Falls. The Granite Falls formation of Sioux Falls has a 100-foot drop in elevation. Below the falls, the elevation varies from 1,281 feet to 1,098 feet at the river's mouth near Sioux City, Iowa.

Associated with the elevation is the slope profile of the river. The slope varies from 1.83 feet per mile near Watertown, 1.50 feet per mile at Sioux Falls, and 0.5 feet per mile at the junction with the Missouri River. The Big Sioux River has a steeper gradient than the James or Vermillion rivers. This steep slope

causes water to move quickly down the drainage system and thus shortens the time of peak flooding in any given portion of the basin.

James River Basin

The James River Basin is the largest of the East River Basin Systems. It is bordered on the east by highlands of the Coteau de Prairie and on the west by the high ground of the Coteau de Missouri. The valley is a nearly flat stretch of land about 216 miles long and averaging 60 miles wide. It is only in the southern portion that the topography becomes steeper. There is little variance in the elevation of the basin. At Columbia, where the river basin forms in South Dakota, the elevation is 1,290 feet. At the southern terminus of the basin near Yankton, the elevation is 1,162 feet.

The James River drainage area encompasses all or part of 23 counties. It drains 12,609 square miles or over eight million acres of land in South Dakota. This represents 16.3 percent of the total land in the state. The river valley is about 400 miles long, 25 to 75 feet deep, and varies in width from a few hundred feet to three miles. The slope of the valley is .493 feet per mile and the average slope of the river is .280 feet per mile.

There are seventeen contributing streams within the James River Valley. These streams drain 10,606 square miles. The majority of the basin lacks good drainage features. This is due to the slight variance in elevation and limited slope of the river. Much of its drainage is noncontributing and remains in small swales and basins.

Vermillion River Basin

The Vermillion River Basin is the smallest of the East River systems. It has its headwaters in the lake country of Kingsbury County. The river flows through McCook, Turner, and Clay counties to join with the Missouri River near Burbank, South Dakota. The west branch originates in Miner County and connects with the main stem near Parker in Turner County.

The Vermillion River Basin is formed in the Dakota Valley or what is more commonly called the James River Lowland. This area is more than 200 miles long and about 60 miles wide and occupies a portion of the lower half of the basin. The gradient of this river system is approximately 400 feet throughout the length of the river. The east branch elevation is 1,518 feet and the elevation near Vermillion is 1,119 feet. The slope profile is approximately four feet per mile.

The drainage system is supplied with water from both the east and west portion of the basin. The major tributaries are the Little Vermillion River, Turkey Ridge Creek, and Saddle Creek. There are also a number of very small tributaries contributing to its drainage pattern.

Black Hills Region

The western most drainage system is found in the Black Hills region. The Black Hills lie within the states of Wyoming and South Dakota with the majority in western South Dakota. The region is 125 miles long and 60 miles wide. The general shape of the Black Hills is elliptical. This formation presents a startling contrast to the surrounding topography. Its eastern side rises from the prairie to a height from 2,600 to

3,500 feet. The western part of the Black Hills varies in elevation from 3,500 to 7,200 feet at Harney Peak.

The major drainage creeks of Alkali, Battle, Bear Butte, Beaver, Box Elder, Elk, French, Rapid, Spearfish, Spring, and Whitewood are all capable of causing heavy flooding and flood-related damage. These eleven creeks drain about 7,500 square miles of land.

Waubay Lakes Chain and Adjoining Closed Basins

The Waubay Lakes Chain is part of a 409 square mile closed basin area in the Big Sioux River Basin in northeastern South Dakota (mostly in Day County). The 10 major lakes in this chain are glacial in origin and include Bitter Lake, Blue Dog Lake, Enemy Swim Lake, Hillebrands Lake, Minnewasta Lake, Pickerel Lake, Rush Lake, Spring Lake, Swan Pond, and Waubay Lake. In closed basins, under most circumstances, water does not have a direct drainage path to a river outside the closed basin and the water would have to evaporate into the atmosphere for lake levels to recede. The northeastern area of South Dakota is much like a giant bathtub. Water fills the basin until it overflows the sides. Because the area is atop a flat area of high ground, the sides of the tub are higher than the normal drainage routes (e.g., the Big Sioux and the James Rivers), leaving the accumulated runoff without a natural outlet.

Rising waters have inundated portions of Day County and the surrounding areas in the past. Significant increases in lake levels within the Waubay Lakes Chain have occurred mainly due to greater-than-normal precipitation along with less-than-normal evaporation. Several presidential declarations allowed for funding to be used to address the immediate problems of inundated roads and structures for emergency access purposes. As of 1999, the federal government had spent over $71 million in northeastern South Dakota for response and recovery efforts and emergency measures. However, because a major storm event or flash flood did not cause the damage (it was caused by an accumulation of annual runoff and a lack of evaporation), established FEMA disaster programs could not adequately address the situation.

Rising water levels in the Waubay Lakes Chain have resulted in substantial damage to public and private properties in the basin. Numerous public roads and highways have been damaged or closed because of high water, and some have been raised at great cost. Many parks and recreational facilities have been adversely affected as well. The available data show that the greatest impacts from flooding have been to agriculture and transportation.

In September 1998, FEMA issued a mission assignment to the U.S. Geological Survey to provide oversight, coordination, and hydrologic expertise for a study of the Waubay Lakes Chain and the adjoining closed basins. This study, including pertinent maps, is on file with the SDOEM and FEMA Region VIII. The U.S. Army Corps of Engineers also provided technical expertise and analysis for the study as well as possible structural mitigation solutions. The Natural Resource Conservation Service provided soils data.

This study found that from 1991 until the report was published in 1999, the Waubay Lakes Chain experienced a wet climatic period that can be expected to occur less than once every 100 years, on average. Due to periods of above normal precipitation and below normal evaporation, significant increases in lake levels and inundation areas within closed basins in northeastern South Dakota have been observed.

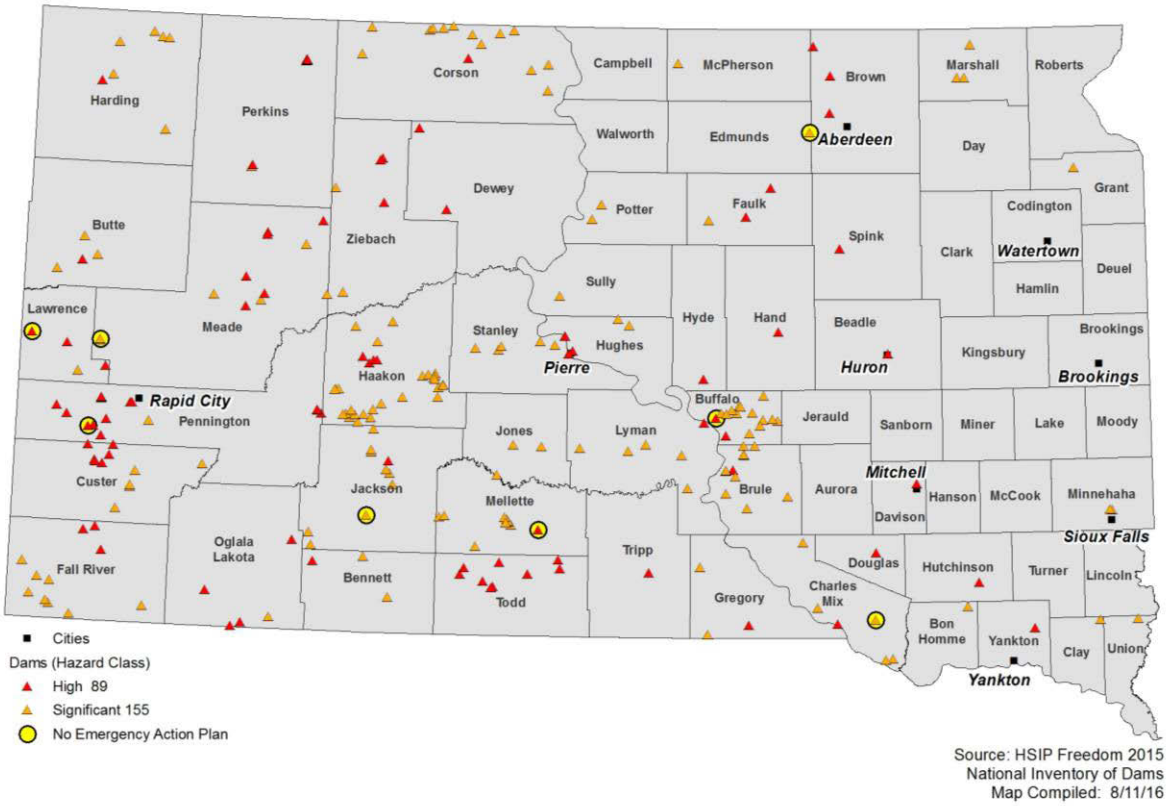
In the Waubay Lakes Chain, the lake levels for Bitter, Hillebrands, Minnewasta, Rush, Spring, and Waubay lakes and Swan Pond have significantly increased. The total surface area of the ten major lakes increased by 74 percent between 1991 and 1998. The water levels for Bitter, Hillebrands, Spring, and Waubay lakes and Swan Pond increased between 15 and 18 feet from 1991 to 1998. Blue Dog, Enemy Swim, and Pickerel lakes have concrete weir outlet structures and experienced lake level increases of 2.7, 1.8, and 0.1 feet respectively between fall 1991 and fall 1998. Minnewasta and Rush lakes experienced lake level increases of 9.2 feet and 3.9 feet respectively.

At the time the study was published, the U.S. Army Corps of Engineers' hydrologic model simulation suggested that flooding problems would persist in the region for the next few years, regardless of whether the climate was wet or dry. It would take at least a decade of drought similar to that experienced in the 1930s to return the lakes to pre-1992 conditions. If relatively wet climate conditions persist, the lakes would continue to climb until Bitter, Blue Dog, Rush, and Waubay lakes form a single lake that will inundate over 60,000 acres and the natural drainage divide south of Bitter Lake could overflow and spill to the Big Sioux River. This scenario, however, would require nearly 15 years of wet conditions.

South Dakota Dams

As mentioned previously, the four largest dams in South Dakota are Oahe at Pierre, Big Bend at Fort Thompson, Fort Randall at Pickstown, and Gavins Point at Yankton. These are U.S. Army Corps of Engineers Dams on the Missouri River. Large dams in the Black Hills are the U.S. Department of the Interior Bureau of Reclamation's (BOR) Deerfield, Pactola, and Angostura dams and the U.S. Forest Service's Sheridan Lake dam. Shadehill Reservoir, while not in the Black Hills, is a significant BOR dam which stores water for irrigation (6,700 acres) and flood control purposes. Figure 3-7 shows the locations of the high and significant hazard dams in South Dakota.

Figure 3-7: South Dakota High and Significant Hazard Dams



More specific location information is in the following section on past events and Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction.

South Dakota Levees

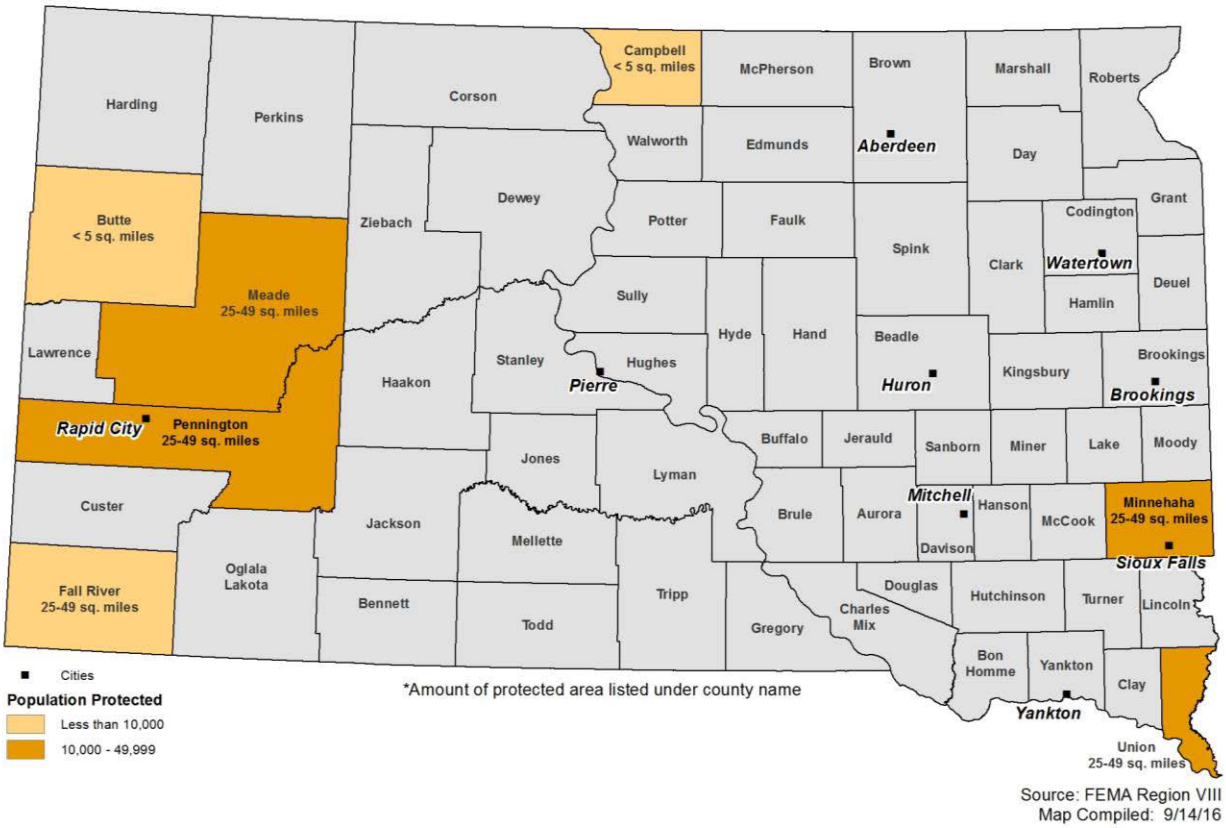
As mentioned previously, South Dakota contains numerous levees ranging from small agricultural levees that protect farmland from high-frequency flooding to urban levees protecting large urban populations and property from larger-less frequent flooding events such as the 100-year and 500-year flood levels. Table 3-9 shows the location of the US Army Corp of Engineers Levees, as well as detail about each levee. These are also graphically depicted on Figure 3-8. The following table is not a comprehensive inventory of levees in the State. The SHMT noted that there are several levees along the James River in Spink and Brown counties that are not certified and frequently overtopped. Although these are not represented in the FEMA database of levees, the James River Water Development District (JRWDD) commissioned a LiDAR survey of the floodplain and now maintains GIS data of all of the levee locations along the James River. This information is being used by the JRWDD to identify specific mitigation actions within the watershed. JRWDD and Brown County are exploring opportunities to commission LiDAR for the entire county.

Table 3-9 US Army Corps of Engineers Owned Levees by County in South Dakota

County	City	System Name	Construction Completion Date	Inspection Rating	Last Routine Inspection Date
Brown	City of Aberdeen	Aberdeen - Moccasin Creek RB	-	Unacceptable	6/3/2015
Butte	City of Belle Fourche	Belle Fourche RB	6/1/1938	Unacceptable	9/9/2014
Campbell	Town of Herrid	Herreid - Spring Creek RB	10/19/1953	Unacceptable	9/8/2014
Fall River	City of Hot Springs	Hot Springs - Fall River Channel West System	7/25/1949	Minimally acceptable	5/27/2015
Fall River	City of Hot Springs	Hot Springs - Fall River Channel East System	7/25/1949	Minimally acceptable	5/27/2015
Lincoln, Minnehaha	City of Sioux Falls	Sioux Falls - Big Sioux RB and Skunk Creek RB	1/1/1961	Minimally acceptable	10/23/2014
Meade	City of Sturgis	Sturgis - Deadman Gulch RB	6/26/1980	Minimally acceptable	9/9/2014
Minnehaha	City of Sioux Falls	Sioux Falls - Diversion Channel LB - South	1/1/1961	Unacceptable	10/29/2014
Minnehaha	City of Sioux Falls	Sioux Falls - Diversion Channel LB - North	1/1/1961	Minimally acceptable	10/30/2014
Minnehaha	City of Sioux Falls	Sioux Falls - Big Sioux RB and Skunk Creek LB	1/1/1961	Minimally acceptable	10/22/2014
Minnehaha	City of Sioux Falls	Sioux Falls - Big Sioux RB	1/1/1961	Minimally acceptable	10/23/2014
Minnehaha	City of Sioux Falls	Sioux Falls - Big Sioux LB and Diversion Channel RB	1/1/1961	Minimally acceptable	10/29/2014
Minnehaha	City of Sioux Falls	Sioux Falls – Big Sioux LB Downtown		Unacceptable	10/30/2014
Minnehaha	City of Sioux Falls	Sioux Falls – Big Sioux River LB South		Minimally Acceptable	10/29/2014
Pennington	City of Rapid City	Rapid City - Rapid Creek RB	11/26/1978	Minimally acceptable	8/13/2014

County	City	System Name	Construction Completion Date	Inspection Rating	Last Routine Inspection Date
Union	City of North Sioux City	North Sioux City - Union County - Big Sioux River RB	10/20/1981	Minimally acceptable	9/27/2014

Figure 3-8 Levee Protection in South Dakota by County



Past Events

According to the National Climatic Data Center Storm Events database, there were 1,302 floods in South Dakota between 1993 and August 2015. Total property and crop damage for these events is estimated at $310.6 million in 2016 dollars. This suggests that South Dakota experiences 62.3 floods and $14.1 million in flood losses (property and crop) annually. There were five deaths and five injuries during this time period. Table 3-10 describes some of the floods that have occurred in South Dakota. See Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction for more information about how floods affect individual counties.

South Dakota is remarkable in that as early as the late 1800s, flood mitigation efforts were pursued and implemented. The first effort was after the 1881 flood of the Vermillion and Missouri rivers that wiped out the town of Vermillion. The town was relocated on the bluffs behind the former town to prevent another recurrence. This was the first recorded hazard mitigation effort by a government entity in South Dakota and possibly the nation.

The second effort followed the 1972 Black Hills/Rapid City flood. This flood stands out in South Dakota history as the deadliest and most expensive in terms of damage. Following the flood, Rapid City refused to allow rebuilding in the floodway, effectively launching federal government efforts to create a hazard mitigation program.

While there have been failures of low hazard dams in recent years, no deaths or injuries were reported, and property damage was minimal. The only significant failures of high hazard dams are the breach of Canyon Lake Dam in 1972 (Rapid City flood) and the failure of Menno Dam in 1984 (see event descriptions below). Rose Hill Dam in Hand county failed in 2010 due to heavy rains. Two people were stranded, hanging from a tree as floodwaters rushed passed, until first responders were able to rescue them.

Table 3-10: Significant South Dakota Flood Events

Date	Comments
June 24, 2015	Strong thunderstorms over western and central Pennington County dumped three to four inches of rain during the evening and overnight hours of June 23-24. Runoff from the heavy rain caused areas of flooding along streams. Runoff from heavy rain caused flooding in Rapid Valley. Green Valley Drive was flooded for a quarter of a mile and Anderson Road was impassable. Flooding was also observed at two gauging stations along Rapid Creek. The river gauge near Rapid Valley crested 2.1 feet over flood stage and the river gauge at Farmingdale crested 0.9 feet over flood stage. Total property damage in those counties is estimated to be more than $20,000.
June 4, 2015	Heavy rain over Fall River County and adjacent areas of Nebraska and Wyoming caused widespread flooding across most of southern Fall River County. Hat Creek, Horsehead Creek, and the Cheyenne River downstream of Angostura Reservoir and their tributaries flooded. Flooding in Oral occurred after runoff backed up at a plugged culvert along Sand Creek. East Oral Road was underwater, with several homes and businesses in Oral and north of East Oral Road inundated. Total property damage in those counties is estimated to be more than $105,000.
June 1, 2015	Additional runoff from several heavy rainstorms continued to cause minor to moderate flooding along Spring Creek upstream of and downstream from Sheridan Lake. Releases from Pactola Reservoir reached 500 cubic feet per second, which combined with the heavy rain, caused minor to moderate flooding along Rapid Creek from Pactola Dam to the Cheyenne River. Many roads were flooded by heavy rain and high stream levels. On the north side of Rapid City, 143rd Avenue was underwater near Neva Way. In Rapid Valley; Reservoir Road, Green Valley Drive between Reservoir Road and Greenfield Road, South Valley Drive, the east end of Dunn Road, Anderson Road, South Radar Hill Road, and Antelope Creek Road were flooded. Around Box Elder; Elk Vale Road just north of Interstate 90, 155th Street south of Highway 14-16, and the South Ellsworth Road bridge were flooded. Hammerquist Road and 157th Street in the

Date	Comments
	Caputa area were closed. Palmer Gulch Road east of Hill City was underwater. Old Hill City Road and the Needles Highway (SD Highway 87) from Playhouse Road to Sylvan Campground were flooded in various areas. At Hart Ranch, the golf course sustained flooding and debris damaged foot bridges. Spring Creek reached the bottom of the bridge at Mulligan Mile Crossing. High water damaged private bridges in Magic Canyon west of Rapid City. Total property damage in those counties is estimated to be more than $700,000.
May 19, 2015	Record flooding occurred along the White River from the Nebraska state line to Badlands National Park. The White River was over 200 yards wide and at least two feet deep on BIA Highway 41 north of Oglala, where a vehicle was swept off the highway and the passengers had to be rescued. BIA Highway 32 near Slim Butte was washed out and a culvert on BIA Highway 27 washed out and the road was damaged north of Rockyford. Total property damage in those counties is estimated to be more than $20,000.
June 14-18, 2014	Repeating heavy rain caused record flooding of the lower Big Sioux River from June 15th through June 26th. Considerable flooding of farmland and other lowlands included numerous roads, with some roads damaged and a few washed out. A few farm homes and other buildings were damaged by floodwaters. There was considerable damage to counties including Union, Minnehaha, Lincoln, Turner, Jackson, Lake, Yankton, Clay, Hutchinson, McCook, Moody, Butte, Harding, Meade, Perkins, and Ziebach. Repeated heavy rains caused record flooding of the Big Sioux River. Farmland and other lowlands including numerous roads were flooded. Some roads were damaged, and some secondary roads were washed out. A few farm homes, other farm buildings, and some fences were damaged by floodwaters. The river crested at a record 12.92 feet above flood stage at Hawarden, Iowa on June 17th. Interstate 29 was temporarily closed along a 22 mile stretch to facilitate levee building to divert some Big Sioux River water to McCook Lake, but the Interstate was re-opened when the river crested at a lower level than was feared. A levee breach across the river from Akron, Iowa, briefly aggravated lowland flooding before it was repaired. Total property damage in those counties is estimated to be more than $1 million.
October 11, 2013	Heavy rain falling on snow remaining from the October 3-5 blizzard caused flooding over portions of western South Dakota. One to three inches of rain fell on October 10 and 11. The runoff and melted snow caused flash flooding in Keystone and flooding along creeks and streams on the plains of western South Dakota. Water covered Elk Creek Road and Antelope Creek Road north of Box Elder, Curlew Road and Pioneer Road north of New Underwood, and Coyote Lane and Golden Valley Drive north of Rapid City. Some fields and pastures in southern Meade County also flooded. The river gauge on Elk Creek at Elk Vale Road north of Rapid City reached a height of 12.6 feet, which is 3.6 feet over flood stage. Total property damage is estimated to be more than $50,000.
June 1, 2013	A large upper level low pressure system pushed across the Northern Plains, bringing heavy rain to the northern Black Hills. Embedded thunderstorms produced additional heavy rain, with four to six inches of rain falling over a 24 hour period. Runoff caused minor flooding along the Belle Fourche River and its tributaries. Several county roads were closed or washed out and culverts were damaged. Redwater River, Crow Creek, and several small creeks and streams experienced flooding. Water reached the edge of a house along the Redwater River and some low water crossings were flooded. Total property damage in those counties is

Date	Comments
	estimated to be more than $200,000.
May 29, 2013	Thunderstorms developed along the eastern slopes of the Black Hills and adjacent plains from Nisland to Sturgis to the Rapid City area. As these storms moved toward the northwest, they redeveloped and became stationary over the eastern foothills. As much as six inches of rain fell in a few hours. Flash flooding was reported in Rapid City; Sturgis; and rural areas of Butte, Meade, and Pennington Counties. Runoff from the rainfall quickly inundated city streets, overflowed small creeks, and breached a few private stock dams. After heavy during the early evening caused flash flooding in south central Butte County, additional rain overnight exacerbated the flooding. High water from several tributaries caused minor flooding along the Belle Fourche River, which was two feet deep over the Bismark Bridge east of Vale. Total property damage is estimated to be more than $25,000.
May 5, 2012	Thunderstorms produced large hail, damaging winds, and flash flooding in southeast South Dakota, near and north of Interstate 90, during the evening of May 5th. The flash flooding continued past midnight on May 6th. Heavy rainfall of up to 6 inches caused flash flooding of numerous roads, parks, fields, other low areas, and buildings including homes. At least 90 homes were heavily damaged in Madison by the flooding, including at least two with basement walls washed out. A basement wall of a dentist's business was also washed out, and the basement flooded with 9 feet of water. Numerous personal possessions in flooded homes and businesses were destroyed. The flash flooding included Memorial Creek, and there was a fatality when an out of state visitor drowned attempting to cross the flooded creek. While this fatality and most of the damage was in Madison, many rural roads and fields were flooded in the area, and east to near the town of Wentworth.
March 11 – July 22, 2011	**Severe Storms and Flooding (FEMA-1984-DR)** A deep and expansive snow pack across the area began to melt bringing many areas of flooding to central and northeast South Dakota beginning in mid-March and continuing into early April. Many roads along with countless acres of crop and pastureland remained flooded. Roads, culverts, and bridges were damaged across the region. Several roads were washed out with many closed. Many homes were threatened with some surrounded by water. Rising lake levels in northeast South Dakota also threatened and flooded many homes. Many people had to use four-wheelers to get to their homes. A Presidential Disaster was declared for all of the counties due to the flooding damage. The total damage estimates, including March, were from 4.5 to 5 million dollars for the area. High water and groundwater levels resulting from record precipitation in the previous year contributed to the slowness of any improvement in the flooding situation until the spring. The flooding diminished across much of the area into May. Flash flooding events began in May and continued through July. Heavy rains and thunderstorms produced flash floods around the State. Storms dropped several inches of rain over the already saturated soils in a matter of hours.
September 22-23, 2010	Persistent thunderstorms developed in the late morning over southeast South Dakota and continued through the afternoon and evening. All of the storms through early afternoon produced large hail, with one report of damaging wind gusts. Large hail, heavy rain, and flash flooding were noted during the evening. Some of the flash flooding continued through the night and next day as flooding.
July 21-30,	**Flooding (FEMA-1938-DR)**

Date	Comments
2010	A powerful storm dumped heavy rain causing flash flooding in South Dakota. As much as nine inches of rain fell in the southeastern part of the state, flooding homes and neighborhoods. The heavy rain also forced Sioux Falls officials to discharge untreated wastewater into the Big Sioux River. The storms in late-July affected counties where soils already were saturated and roads, bridges and culverts had been damaged from the earlier flooding and storms. Rain gauge readings ranged from 3.69 inches to 4.15 inches. The National Weather Service says the previous July 21 record at Mitchell was 2.32 inches in 1907. Total damage to public infrastructure in those counties is estimated to be more than $4 million from heavy rains and severe storms during the period between July 21 and July 30, 2010.
March 10, 2010	**Flooding (FEMA-1915-DR)** Floodwaters closed roads, filled basements, and soaked agricultural fields in southeastern South Dakota in late March 2010. A combination of snowmelt, ice jams, and heavy rains drove the Vermillion, Big Sioux, and James Rivers over their banks. Some residents described the flooding as the worst in living memory, according to the Associated Press. This event also resulted in a presidential disaster declaration.
April, 2009 through June 2009	March flooding of the James River continued throughout April. The James River went above flood stage at Redfield on April 18th and continued through the end of the month. The James River at Redfield rose to 25.7 feet on April 30th, almost 6 feet above the flood stage of 20 feet. The James River from Columbia to Ashton was from 6 to as much as 10 feet above flood stage throughout the month. The James River continued to cause major issues throughout Brown and Spink counties for roads, fields, cropland, along with some homes. State Highway 34 was closed for about two weeks at the state border near Hecla. The flooding washed away the highway base. The James River west of Hecla became a 3 mile wide lake. Some people near Hecla said this was the highest the James River had been near Hecla in several decades. The high water forced the evacuation of people from two homes near Hecla. Many roads along the James River throughout Brown and Spink counties were closed. Also, several bridges along the river were overtopped. Many outbuildings along the river were flooded and damaged with over 100 livestock deaths attributed to the flooding. At the Sand Lake National Wildlife Refuge, both the Sand and Mud Lakes hit record levels on the morning of April 17th. Sand Lake's elevation was 1,292.58 feet, breaking the previous record of 1,292.39 feet in 1997. Mud Lake's elevation was 1,293.36 feet, breaking the previous record of 1,293.29 feet. The elevation of the river remained above flood levels through June though waters began receding in early June. This event also resulted in a presidential disaster declaration.
March 20, 2009	Rapid snowmelt and ice jamming caused the Elm River near Westport to rise above flood stage on March 20th. The Elm River reached an all-time record level of 22.69 feet on March 25th almost 9 feet above flood stage. The previous record was 22.11 feet set on Apri1 10th, 1969. The flood stage for the Elm River at Westport is 14 feet. The city of Westport was evacuated with the flood waters causing damage to many homes and roads in and around Westport. Also, many other roads and agricultural and pastureland along the river were flooded. The Elm River slowly receded and fell below flood stage on March 30th. The flood waters from the Elm River flowed south and into the northern portion of Moccasin Creek. Subsequently, the Moccasin Creek rose as the water flowed south into the city of Aberdeen. Flooding became a concern for Aberdeen and for areas along the creek north of

Date	Comments
	Aberdeen. The Governor signed an emergency declaration which allowed the state to help with flood response efforts, including sending 50,000 sandbags to the area. Also, the National Guard was activated to move a variety of heavy equipment. Some sandbagging and a falling Elm River kept the Moccasin Creek from causing any significant flooding in and north of Aberdeen. Although, some township and county roads were flooded from the creek.
June 1 – June 6, 2008	A series of intense storms impacted more than twenty counties across the state over a period of five days, incurring several million dollars' worth of damage and causing flash flooding, hail and wind damages to livestock, wildlife, property and cropland, and resulting in a presidential disaster declaration. Periodic flash flooding continued for another four days, incurring several hundred thousand dollars more of damage.
August 17, 2007	An intense summer thunderstorm dropped rainfall in the foothills of the Black Hills ranging from four to seven inches that caused flash flooding in and around Hermosa. The flash flooding resulted in widespread catastrophic damage to homes and businesses. Some houses were moved off their foundations and destroyed; other homes and businesses received significant flood damage. Critical utilities were also nonfunctional.
May–June 2007	**Severe Storms, Tornadoes, and Flooding (FEMA-1702-DR)** Flooding brought on by record-setting rainfall on May 4 and 5 caused widespread damage to homes, businesses, farmland, infrastructure, and utilities across eastern South Dakota. Houses were destroyed; with basement walls collapsing, and critical utilities were nonfunctional. Thousands of acres of farmland were flooded that could not be planted, resulting in financial impacts to the individual operations as well as businesses dependent on the farming community. State and local governments also sustained damage to infrastructure. Flooding along the James River in Yankton County exposed URD cable. The Bon Homme Yankton Electric Association was forced to relocate the cable. Additionally, the flooding shut down one irrigation system for the entire summer. The Association's emergency repair and restoration costs were estimated at $20,023. www.state.sd.us/news/showDoc.aspx?i=8468 www.state.sd.us/news/showDoc.aspx?i=8437
May–June 2004	**Severe Storms and Flooding (FEMA-1531-DR)** Thunderstorms developed from northern Turner County to western Yankton County on May 29. These storms produced large hail and strong winds across the area and saw very little movement over an eight-hour period. As a result, three to six inches of rain fell in portions of Yankton, Turner, and Minnehaha counties, including Sioux Falls and the towns of Parker, Hartford, Crooks, and Marion. Urban flooding resulted with rapid runoff from streets across Sioux Falls. Willow Creek in Crooks and Skunk Creek in Hartford rose several feet in only a couple of hours. In western Sioux Falls, Skunk Creek reached its highest level in 20 years. River flooding continued the following two days. On June 16, strong thunderstorms developed in western Sioux Falls and moved east. As the storms moved east, new storms developed just west of Sioux Falls, resulting in repeated episodes of heavy rain in the Sioux Falls metropolitan area. Rainfall amounts were similar to May 29, but the rate of rainfall was much higher. Over two inches of rain fell in one hour at the Sioux Falls airport, and multiple locations around the city received more than three inches of rain in two hours. The

Date	Comments
	highest amount of rainfall reported in Sioux Falls was 7.79 inches. There were numerous reports of three to six inches across the city. The large amount of rainfall in a short period of time produced excessive runoff across the city and Skunk Creek and the Big Sioux River rose rapidly as a result. At the time, the 31 days up to and including June 16 marked the wettest 31 day period on record for Sioux Falls (12.74 inches at Joe Foss Field). Source: NWS Sioux Falls
April 2001	**Severe Storms (Flooding) (FEMA-1375-DR)** This presidentially declared disaster was precipitated by an onset of flooding that began during a spring thaw in early March 2001. On April 6, a series of rainstorms that dropped from two to six inches of rain resulted in flooding of the James, Vermillion, and Big Sioux rivers. According to the National Weather Service, the James River, at Huron, reached its highest crest of 18.1 feet (flood stage of 11 feet) on April 10, the second highest crest on record. On April 11, a second similar weather system produced more heavy rains in the Aberdeen, Huron, Watertown, and Brookings areas. Flooding of the James River occurred in and around Huron and Mitchell. The west fork of the Vermillion River caused flooding around Parker and Centerville. The Big Sioux River flooded in and around Watertown, Dells Falls, and Sioux Falls. At Mitchell, the James River reached its highest crest of 21 feet (flood stage of 14 feet) on April 11, the second highest crest on record according to the National Weather Service. Peak crests on the Vermillion and West Vermillion rivers were two to four feet above flood stage. The Big Sioux River in Sioux Falls crested at 22 feet (flood stage of 16 feet) on April 24. A third major system passed through South Dakota on April 21-22. The Black Hills, in the western part of the State, received up to 22 inches of heavy wet snow and the eastern portion of the state received 4-8 inches. Beadle, Brookings, Brown, Buffalo, Clark, Codington, Day, Deuel, Edmunds, Grant, Gregory, Hamlin, Hanson, Jerauld, Kingsbury, Marshall, Mellette, Moody, Roberts, Sanborn, Spink, Todd, Turner, and Tripp counties were included in the disaster declaration. The major impact was to public infrastructure. Due to ice and wind damage to utility poles and lines, electrical services to some areas were interrupted. Numerous bridges and roads were impacted as well. There was damage to county and township roads in the eastern and northeastern portion of the state that had previously not been affected by floodwater. Some of the damaged roads included school bus, mail, and farm-to-market routes. Travel on these roadways involved significant risk. Several roads were temporarily impassable, requiring residents to travel greater distances because of detours. Many farmers were unable to access their fields to begin spring planting. In Mellette County, ice jam fluctuations substantially damaged a bridge, which caused the county to close the bridge to through traffic, resulting in a 40-mile detour for residents needing to cross the White River. This disaster also heavily impacted South Dakota's agricultural and livestock community.
February–May	**Severe Storms/Flooding (FEMA-1173-DR)**

Date	Comments
1997	This disaster had its roots in past flooding events. Beginning in 1992, the state had a series of weather-related events of sufficient magnitude and impact to warrant eight presidential disaster declarations prior to this event; five for flooding, four for ice/snow; and one for just snow. These events kept the water table saturated, which prevented much of the winter snow melt and the spring/summer rains from soaking into the ground, thus contributing to flooding. The first significant winter storm of 1996 hit the eastern part of the state in mid-November, dumping up to 10 inches of snow across the northeast and producing a major ice storm with widespread damage across the southeast (see Winter Storms). In 1997, major winter storms were fairly frequent throughout January with several blizzards, mostly in the northeast part of the state (see Winter Storms). From mid-November to mid-February, the general weather across the eastern part of the state was cold and wet with below normal temperatures (in excess of 30°F below zero) and record-setting above normal snowfall. The persistent cold greatly limited snowmelt between storms, allowing up to 48 inches of snow to accumulate across much of the northeastern part of the state. Mid-February snow depths elsewhere across eastern South Dakota ranged from 10 to 24 inches. The National Weather Service snow water equivalent measurements of February 12 ranged from approximately two inches near the Missouri River to over six inches in Marshall County. Snow water equivalent values from 4 to 5 ½ inches were common over the central and northern portions of the James and Big Sioux river basins. Seasonably cool and relatively dry weather prevailed across the eastern part of the state from mid-February to early April. An early April blizzard added to the remaining snow pack, which gradually melted south to north by the end of April. Heavy rain and snowstorms in April, compounded by severe winter blizzards and existing saturated soil conditions, resulted in persistent flooding throughout the state. Many people were evacuated from their homes and farms, while others had limited or no access or escape. Heavy snowmelt and pounding rains turned prairie potholes into lakes, pushed people from their homes, and prevented farmers from planting thousands of acres of land. The James River Water Development District estimated that five years of flooding destroyed or severely damaged approximately 75 percent of the forested areas in the James River Valley. Riverine flooding destroyed or damaged many homes and businesses, impacted water and sewage treatment plants, and damaged or destroyed many roads and bridges. All counties were included in the presidential disaster declaration. This flood caused approximately $82.5 million in damage (2006 dollars) and two deaths.
March–May 1995	**Severe Storms, Flooding (FEMA-1052-DR)** The entire state had above normal precipitation between January and May, ranging from about one to two inches above normal in the southwest to five to nine inches above normal in the east. This is up to 200 percent of normal. Many official reporting stations, including Huron, Mitchell, and Sioux Falls, experienced their all-time wettest springs on record. Most damage to public facilities was caused by ground saturation and flooding due to very high residual groundwater tables from 1994, heavy winter snow and spring rain, and rapid snowmelt. Many roads were under water or unusable due to high groundwater saturation of the subgrade,

Date	Comments
	causing interruption of emergency services. Damage to power transmission and distribution facilities owned by rural electric cooperatives was also reported. Preliminary damage surveys identified over 3,000 homes with some type of damage. The vast majority of damage was from one to three inches of groundwater seepage into basements. In many areas, the water table rose to near land surface levels, saturating septic drain fields and preventing proper treatment of residential sewage. Preliminary damage surveys estimated $9.3 million in damage to infrastructure of public facilities. Roads and Bridges and Utilities incurred the most damage with almost $5.7 million and $2.6 million in estimated damages, respectively. Federal aid system roads received $7.1 million in damage.
March–July 1994	**Severe Storm/Flooding (FEMA-1031-DR)** Flooding in northeastern South Dakota began in mid-February 1994, as a result of very high residual groundwater tables from 1993's extremely high levels of precipitation (snow and rain) and rapid melting of the snowpack. Flooding continued into late March 1994 and then subsided. Rain continued throughout the spring and summer months, but the remainder of the snowmelt was gradual and did not significantly contribute to flooding. On July 6, a significant storm system passed through central and northeastern South Dakota. Severe winds caused damage in the Pierre area, and the town of Milbank in Grant County received approximately six inches of rain in a two to three hours. The thunderstorm in Milbank caused the town's storm and sanitary sewer systems to overload and water backed into basements of several homes. Damage was estimated at approximately $4 million. The vast majority of damage was to county and township roads (which had significantly deteriorated because of saturation from near ground-level water tables), culverts, and bridges. Many roads remain under water, as once-small (or dry) glacial lakes with no drainage outlets, grow in size and encroach upon nearby roadways. In 1995, total damages were estimated to be $36.5 million.
March–September 1993	**Flooding, Severe Storms, Tornadoes (FEMA-999-DR)** Early and rapid snowmelt resulted in localized flooding along portions of the three eastern river basins. Major problems began in May when severe weather spawned tornadoes and floods in five eastern counties, injuring 12 and killing 1. Heavy rains continued throughout May, June, and July, which included a 6.5 inch deluge in Sioux Falls on May 23 that backed up sewage into 190 basements and damaged city streets. By the end of June, the Big Sioux River was over a mile wide in places, flooding many communities along its banks. During early July, the swollen Vermillion and James rivers inundated thousands of acres of farmland and surrounding communities. Heavy July rains developed flash flood torrents on small drainages in Madison and Yankton, while rising lake levels flooded numerous communities on lake shores. Overall, the disaster heavily impacted 39 counties in South Dakota, over half the state, and contributed to four deaths, approximately $2 million damage to business, $12 million damage to public facilities, $10 million to private residences, and $204 million to agriculture. Federal aid system roads received $3 million.
June 1992	**Flooding, Severe Storm, Tornadoes (FEMA-948-DR)** On June 13 and 14, a major spring storm resulted in severe weather in Harding County. Golf ball size hail and 10 ½ inches of rain occurred in a three-hour time span. Crops were destroyed and over 500 sheep were killed. On the afternoon and evening of the June 16, several violent thunderstorms (super cells) produced large amounts of rain and several large, damaging tornadoes. Heavy rain was

Date	Comments
	experienced in the Davison, Miner, Kingsbury, Lyman, Buffalo, Moody, Brookings, Deuel, Minnehaha, and Hamlin counties. The heavy rains occurred in an area already saturated by previous rains. Over a two to three day period, 15 to 20 inches of rain fell in the Clear Lake/Watertown area resulting in widespread flooding of the Big Sioux River. The rains subsided late in the week. Some flooding was experienced by South Dakotans as far south as Sioux Falls.
May 1986	**Severe Storms, Flooding (FEMA-764-DR)** The above average fall rains and heavy winter storms during 1985-86 created a condition of supersaturated ground and record water levels in the lakes and Big Sioux River Basin in the northeast part of the state. The snowmelt run-off into the numerous lakes forced the already full lakes to overflow and seriously impact residences, cottages, resort business, and agribusiness. A severe winter storm covered the entire state the week of April 14, adding one to three inches of precipitation to the area. Flood damage was estimated at approximately $25.9 million, $20.6 million of which was to agriculture.
Spring 1984	**Severe Storms, Flooding (FEMA-717-DR)** The winter of 1983-84 was the third snowiest on record (75 inches of snow at Sioux Falls). The heaviest snows occurred in November 1983 and in March 1984. Severe snowmelt flooding began March 20 and after the fourth wettest April on record, caused near record flooding on the Big Sioux, Vermillion, and lower James rivers in April. These rivers did not go below flood stage until the end of April. Numerous reports of water damage were recorded in the communities of Mt. Vernon, Parkston, Tabor, and Volin. June was the wettest June on record in southeast South Dakota and was the sixth wettest month on record at Sioux Falls. Between June 4 and June 22, many large storms crossed the region and dumped approximately 30 inches of rain, which caused repeated flash floods. Numerous roads and bridges were heavily damaged. Many areas had severe urban flooding, because sewers and storm drains were unable to handle the load. As a result, many basement walls collapsed. The Lake Menno Dam (Hutchinson County) collapsed on June 12, killing 450 hogs, destroying one car and damaging two, moving a farmhouse 75 feet off its foundation, scattering and destroying farm machinery, and completely sweeping away grain bins. On June 16, three feet of water was flowing through downtown Davis (Turner County). Vermillion Lake Dam (McCook County) and many smaller dams sustained severe erosion. The Fulton Lake Dam (Hanson County) was severely weakened and in imminent danger of failing, but held. On June 18, a train was derailed at Parker (Turner County) due to washed out tracks. On June 20, Lake Dimock Dam (Hutchinson County) gave way, destroying the dam and causing flooding in Milltown. A 400-yard sandbag dike saved the Lake Carthage Dam (Miner County) from destruction. Widespread flash flooding caused severe erosion; washed out or weakened many roads, bridges, and culverts; and washed away crops in low lying areas. Many small stock dams collapsed, washing out roads, bridges, and culverts beneath them. In Mt. Vernon (Davison County), there was three to four feet of water in homes.

Date	Comments
	Twenty homes were evacuated along Dry Run Creek in Mitchell (Davison County). Sewage was five to six feet deep in parts of Mitchell. Estimates by the U.S. Geological Survey place the flooding on the Big Sioux River drainage at about a 10 to 30 year recurrence interval, the Vermillion River at about a 100–500 year recurrence interval, and the lower James River at about a 100–300 year recurrence interval. By June 22, over one million acres of cropland in the region were under water. Total damage was estimated at $289 million.
Spring 1983	The winter of 1982–83 was the fourth snowiest on record and led to severe snowmelt flooding on the lower Big Sioux and Vermillion rivers from late February to mid-March (March '83 was the fifth wettest on record). Heavy rains through April and into early May prolonged flooding and high stages on these rivers through the middle of May. Very heavy rains again in mid and late June caused flash flooding in the area and again caused severe flooding on the lower Big Sioux River and near record flooding on the lower Vermillion River. The flash flooding in June caused widespread erosion and crop damage and there was severe agricultural land flooding on the mainstreams of the lower Big Sioux and Vermillion rivers.
Spring 1979	Big Sioux River—A minor flood in North Sioux City was caused by an ice jam. Lake Kampeska—A minor flood affected property on the lake shore.
June 1976	**Flash Flooding, Mudslides (FEMA-511-DR)** In a 24-hour period on June 13-14, 3 to 10 inches of rain fell in the northern Black Hills. And additional two to three inches of rain plus heavy snow was recorded over this area on the June 15 and 16. The run-off from this precipitation did considerable damage in the counties of Lawrence, Meade, Butte, and Harding. Physical structures, streets, roads, sewers, and water systems sustained about $1.5 million in damage. Deadwood, Spearfish, Belle Fourche, Sturgis, and Galena received most of this damage. Throughout the region, a number of bridges and culverts were washed out and many of the roads suffered water erosion. Debris damage was not as great as in 1972, however, there was considerable movement of rocks and gravel. There was also a problem with mudslides and landslides. One death resulted from this flood.
June 1972	**Heavy Rains, Flooding (FEMA-336-DR)** On June 9-10, 1972, extremely heavy rains over the eastern Black Hills of South Dakota produced record floods on Rapid Creek and other streams in the area. Scattered showers had occurred throughout the Black Hills area on several days prior to the heavy rains that began on June 9. Near Pactola Dam, these earlier showers left the soil saturated, which increased the amount of runoff for the flood of June 9-10. Rainfall began in the Black Hills area on the afternoon of June 9, when a group of almost-stationary thunderstorms formed over the eastern Black Hills. Precipitation totals for June 9-10 ranged from 4 inches to more than 12 inches in the Rapid Creek watershed between Pactola Dam and Rapid City. In the Boxelder Creek watershed, 15 inches of rain during a six-hour period was measured at Nemo. The heaviest rainfall averaged about four times the six-hour amounts that are to be expected once every 100 years in the area.

Date	Comments
	The resulting runoff produced record floods (highest peak flows recorded) along Battle, Spring, Rapid, and Boxelder creeks. Smaller floods also occurred along Elk Creek and Bear Butte Creek. The floods struck quickly and forcefully, but they did not last long nor did they make much impact farther downstream in the basins. Nonetheless, the Black Hills region sustained millions of dollars of damage to roads, streets, and bridges (very few bridges were left standing). Rapid City—Evacuation of residents along Rapid Creek was ordered by 10:15 p.m. Flood and debris-laden water flowed into Canyon Lake and clogged the dam's chute spillway. This caused a 300-foot breach in the dam and sent a wall of water and debris pouring down on residents below the dam. The effect of this dam failure on the subsequent flood wave into urban Rapid City has been difficult to assess because the amount of water coming down Rapid Creek and several tributaries (accounting for 86 percent of the peak flow) far overshadowed the amount of water in the small lake. The peak flow was carried through Rapid City via Rapid Creek at about midnight on June 9, while many people were asleep and unaware of the impending flood. The stage of Rapid Creek (measured above Canyon Lake) rose more than 13 feet in five hours during the flood. The toll of the flood-produced carnage was staggering. At least 238 people died (including 5 listed as missing and presumed dead). Thousands of people barely escaped death and hundreds of people were forced to climb, stand, or cling to objects which saved them from being swept away. Property damage exceeded $79 million. 436 houses were destroyed and 930 houses damaged. 710 mobile homes were either damaged or destroyed. 36 businesses were wiped out and 236 more sustained damage. About 5,000 cars were reported lost to the flood. Keystone—Motels, shops, bars, and restaurants, which cater to tourists were either damaged or destroyed. Many campgrounds located along the creeks were washed away. At least 10 campers died. Total damage was set at $1.4 million. Black Hawk and Box Elder—These cities incurred $2 million in damage as the flood destroyed or damaged 75 homes and 180 mobile homes along Box Elder Creek. Sturgis—Sturgis sustained over half a million dollars in damage; 275 houses and 25 businesses were affected.
Spring 1969	**Flooding (FEMA-257-DR)** Big Sioux River—This flood surpassed the flood of 1881 in magnitude with water discharge rates more than twice those of 1962. It resulted from a large buildup of snow. Snow fell in December (1968) in normal amounts, but the accumulations for January and February set a record. The temperatures during March were below the seasonal average, so little run-off occurred. The entire basin was ice free by April 6. The upper part of the basin received an inch of rain on April 7 and compounded the flood. One-eighth of Watertown was under water. Dempster, Estelline, and Castlewood had flood damage as did the lower portion of Dell Rapids. Fifty families were evacuated from Moody County, and fifty people had to be removed from Renner. Sioux Falls was more fortunate as they had developed a flood control system, which was credited with preventing more than $12 million in flood

Date	Comments
	damage. Vermillion River—This flood was greater than the 1962 flood. The town of Centerville was surrounded by water. Within the town, the sewers backed up and the disposal plant was flooded. In the surrounding country, the damage was about the same as in the previous floods. Three bridges were washed out and numerous roads damaged. 450 feet of one highway was completely washed away. The dike system did not contain the water and the lowlands flooded. The U.S. Geological Survey placed the damage to the basin at $1 million. James River—The river was in flood during all of April. The creeks in the lower portion of the basin started flooding early in the month. Their discharge of water started breaking up ice on the main stem of the James. The massive flow of the smaller tributaries caused a backing up of water along the James and increased the problem of flooding. Huron recorded a flood crest of 16.7 feet, almost one foot higher than registered in the previous 30 years. In that area, damage was estimated at $750,000. In the northern part of the state, Moccasin Creek flooded from water coming out of Richmond Lake. This caused some flooding in Aberdeen, as well as extensive flooding in the surrounding countryside. Total damage to the basin was over $16 million. Most of the damage was incurred by farm land, bridges, and roads.
May 18, 1965	**Flooding (FEMA-197-DR)** Black Hills—Flash flooding brought widespread damage to Deadwood, Spearfish, and Sturgis. Heavy snows in excess of 30 inches and 7 inches of rain triggered an avalanche of water shooting down the creeks and gullies. Some houses were swept away in the Spearfish-Sturgis area while others sustained major damage. One resident whose home was near a creek lost everything. He reportedly had a 70 ton concrete retaining wall between the house and the creek—this was completely washed away. Flood damage to the Black Hills area was estimated at over $2 million.
Summer 1962	**Flooding, Tornadoes (FEMA-132-DR)** Black Hills—A summer storm dumped more than three inches of rain on Rapid City. The resulting damage: 120 mobile homes, 2 motels, and over 400 homes had water damage. Bridges, roads, sewer systems, streets, and recreation areas along Rapid Creek were also damaged. Total damage to Rapid City alone was over $800,000. Sturgis, Deadwood, and Whitewood received extensive damage to roads and bridges. Road equipment lost during this flood was estimated at $200,000.
Spring 1962	Big Sioux River—Snow and ice were the cause of the devastation. Ice jams were a serious problem as they held back the run-off. From Brookings to Sioux Falls, ice caused problems. Flandreau and Renner also had flooding because of the ice. Farther north, flooding also occurred. Watertown received flooding from Willow Creek, Lake Kampeska, and the Big Sioux River. The U.S. Army Corps of Engineers estimated damage by the Big Sioux River to be $2.5 million. The interstate bridge near Sioux City collapsed—replacement cost was $600,000. Vermillion River—One of the worst for the southern segment of the basin. This

Date	Comments
	flood resulted from snow melt and ice buildup. The towns of Centerville and Davis reported minor flooding. The majority of the flooding impacted the farm country. Thousands of acres of land were submerged. The highway system received heavy damage. Five bridges in Turner County were washed out and many roads were closed. The damage to the roads and bridges was estimated at $60,000.
April 1960	**Floods (FEMA-99-DR)** Vermillion River—Between 10 and 15 thousand acres were flooded when the dikes were unable to retain the rapid run-off. Many fences were destroyed due to ice and debris pile up. Also, county road systems were damaged due to erosion. The town of Davis received about one foot of water.
March 1960	Big Sioux River—Flooding occurred from the Brookings area south to the junction with the Missouri. Deer Creek and Medary Creek caused flooding in Aurora. Bruce and Sioux Falls also experienced flooding. Damage was heavy and estimated at $2.3 million. Approximately half of this was incurred in the lower basin. About 86,000 acres of land were flooded, and 41,000 of these were between Sioux Falls and Sioux City. James River—The U.S. Geological Survey reported that severe flooding occurred north of Huron with flood water lingering in the area. Tributaries in the Mitchell area also presented flood problems. Pony Creek, which flows through Parkston, rose to flood stage in three hours. People living along its banks had to be evacuated. A number of culverts and bridges in the town were jammed with debris. North of Mitchell, Dry Run Creek flooded, causing at least five families to be evacuated.
June 17, 1957	General Comments: Rated as a 10 to greater than a 100-year event. Five deaths. Attributed solely to rain. Big Sioux River—An estimated seven inches of rain fell in the Flandreau and Sioux Falls area. The Skunk and Marne creeks as well as the Big Sioux River were in flood stage. The towns of Flandreau, Egan, Baltic, Trent, Sioux Falls, and Canton were all impacted by the flood. Sioux Falls had flood damage to the north and southern parts of town as well as heavy flooding in the business district along the river. Damage was estimated to be over $1 million in the city and $4 million over all. Of this amount, $980,000 was sustained in the southern half of the Big Sioux River Basin—over 62,000 acres of land were flooded. Families were forced from their homes, and many of the houses were flooded. Most of the crops in the area were destroyed by the water and there was little or no chance to replant because of the short growing season. Vermillion River—The sudden rain that fell during the middle of June dropped between three and eight inches of precipitation throughout Turkey Ridge Creek and the Vermillion River north of Centerville. The citizens and National Guard filled sandbags to be used in and around Centerville. An estimated 50,000 sandbags were placed on the lowland dike system south of the town to help contain the water. An estimated 80 square miles were flooded. James River—The southern portion of the basin was also affected. The tributary of

Date	Comments
	Marne Creek erupted with a flash flood which brought considerable water and debris to Yankton. Several homes and businesses adjacent to the creek received water and mud damage.
May 1952	Rapid City—Heavy flooding through the Canyon Lake area of west Rapid City. Damage was very much like that sustained in the 1972 flood. Sturgis/Deadwood—Heavy rains brought flash flooding that tore up streets and gas pipelines in Sturgis. Bridges were washed out and water erosion caused rock slides. Water damage and landslides also occurred in Deadwood.
April 8, 1952	Big Sioux River—Warm weather brought on another rapid snow melt and flooding conditions. Watertown had flooding starting at Lake Kampeska. There was also heavy flooding in the southern part of the town. Farther downstream at Estelline, the river was about one mile wide. Flooding occurred in the towns of Flandreau, Trent, and Dell Rapids. There was also heavy flooding around the Sioux Falls Air Base (Joe Foss Field). Pictures of the locality gave it the appearance of a large lake. From Watertown to Sioux Falls, about 99,000 acres were flooded and $4.5 million of damage sustained. Below the falls to the mouth of the river, an additional 30,000 acres of land were covered and about $1 million damage done to the area. James River Basin—The tributaries of the Elm and Maple rivers delivered snowmelt run-off over thousands of acres of farmland. Ice jams on the Elm and Maple rivers forced the water over land. Hundreds of farm families were isolated by the water, while other families in the area were still snowbound. The end result was an enormous amount of water standing on frozen ground, causing the Elm River to spread to one mile in width. This water washed out a number of culverts and roads and isolated farms.
Spring 1951	Big Sioux River—Heavy flooding originated in the Brookings area. An accumulation of snow throughout February and an additional six to fourteen inches during March served as the flood source. High temperatures in late March brought about rapid melting and the flood condition. The Big Sioux was ½ mile wide in Moody County, 1 ½ miles wide around Baltic and Sioux Falls, and 2 miles wide below the Rock River. The area from Brookings to below the falls of Sioux Falls had about 73,400 acres of land flooded and damage of nearly $2.25 million. The area from Sioux Falls to Sioux City, Iowa, had an estimated 29,000 acres flooded and $600,000 in damage. Vermillion River—The combination of snow melt run-off and ice dams brought extensive water to the town of Davis. The entire main street of the town had water damage. One portion of town had three inches of water, which caused a number of families to evacuate. Elsewhere, the towns of Centerville and Montrose received some water. At least three bridges were washed away, lowlands were flooded, and some stored grain destroyed.
Apr/May 1950	Grand, Moreau, and James rivers—10- to 25-year flood event. Much of the damage was the result of water lingering over the fields. Parts of Brown County and adjacent counties had flood conditions for more than a month. More than 40,000 acres of cropland were submerged and damage was greater than $900,000. Flooding also created heavy damage to road surfaces and caused the loss of some grain and livestock. Total damage was estimated at $5 million.

Date	Comments
May 1922	Cheyenne and James river basins—25-50-year flood event: Caused by snowmelt and rain.
May 1920	Rapid City—Homes were flooded, bridges were washed out, and utility systems disrupted. Hat Creek and James River—25-50-year flood event: Caused by snowmelt and rain. Deaths: 7.
Jun 12, 1907	Rapid City—Caused by more than five inches of rain throughout the Black Hills in one six-hour period. The flood destroyed five bridges, damaged roads and power lines, and washed out about ½ of Canyon Lake Dam. The entire downtown area along Rapid Creek was under water. Four people died, and the railroad system sustained heavy damage.
May 1883	Rapid City—Similar flood to 1878: bridges, buildings, and homes received heavy water damage.
Spring 1881	Big Sioux River—Winter began in mid-October 1880. The total winter was very cold and an accumulation of two to four feet of snow covered the state. When the ice broke up in March, the Big Sioux River Basin was flooded. Sioux Falls was especially hit hard. The river was recorded as rising 16 feet in 24 hours on March 20, 1881. The rapid rise brought widespread destruction throughout the Sioux Falls area. Approximately 100 buildings in north Sioux Falls were washed away. Three major bridges were also washed out in a 15-minute period. Estimated damage was $150,000 to the Sioux Falls area. Below the falls, farms along the river suffered heavy flood damage. Large amounts of grain, livestock, and personal possessions were lost to the flood. Many of the railroad bridges and wagon bridges were washed away. The only means of travel was by foot or horseback. No lives were lost. Vermillion River—The town of Vermillion was located on the banks of the Missouri and Vermillion Rivers. Almost all the homes and stores were located along or near the shoreline. The heavy accumulation of winter snow started melting, which caused the Missouri River to flood. Associated with the flood was ice blockage, which not only backed up the water into the Vermillion River but also formed an ice dam that prevented normal run-off. The tributary run-off added to the back water until the river became one to two miles wide in places. Mills, houses, and stables were washed away. When the Vermillion River finally broke through the ice blockage, the impact was devastating. A wall of water entered the town of Vermillion and covered it in depths ranging from 3 to 10 feet of water. The combined forces of the Missouri and Vermillion rivers resulted in the town literally floating away. An estimated 132 buildings were destroyed and many others were damaged by the ice and water. The end result was ¾ of the town was totally destroyed and about $142,000 in damage was sustained. This destruction was so total and severe that the town was relocated on the bluffs behind the former town to prevent another recurrence.
1878	Rapid City—Rapid Creek rose 20 feet in one hour. Streets were under water, buildings flooded, and bridges washed out.

Source: If not otherwise sourced in the table, the NCDC is the information source.

Probability

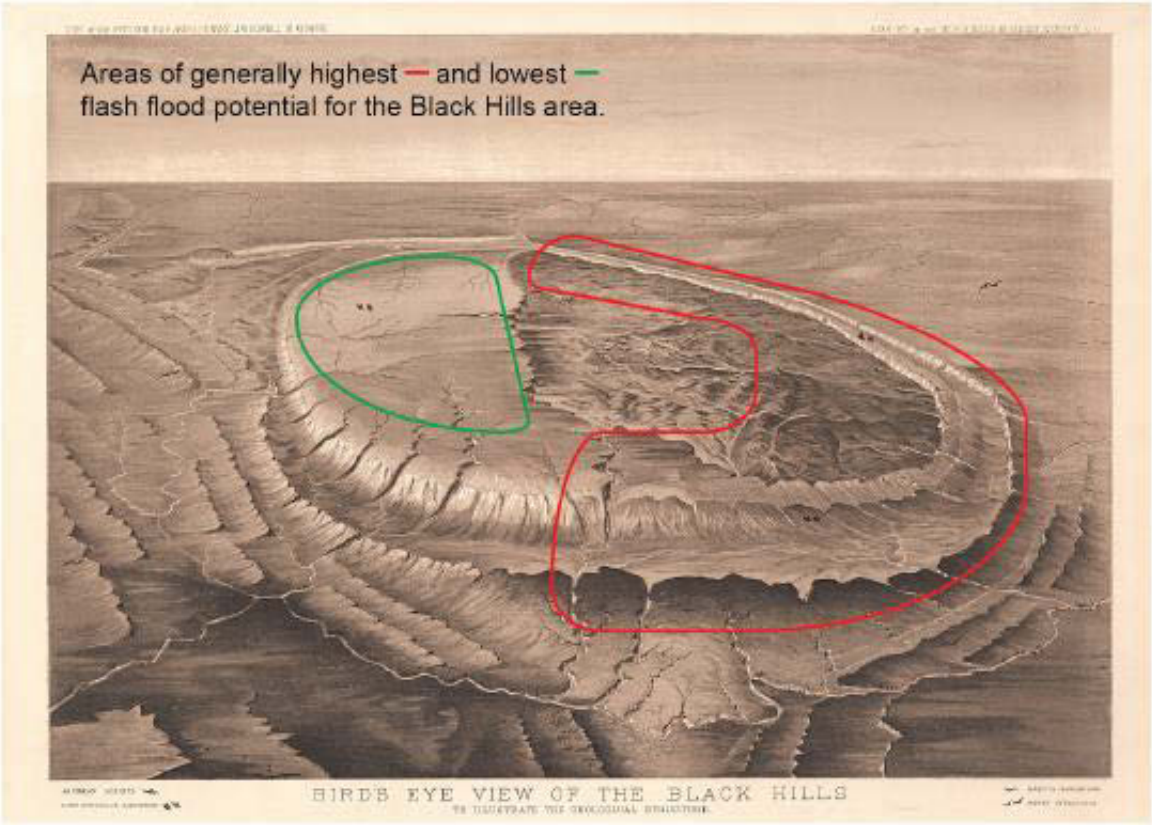
FEMA flood studies provide mapping and detailed flood information for floodplains where the water body has a one percent chance of occurrence in any given year in identified special flood hazard areas. Smaller and more frequent damaging events occur in the state on an annual basis. Floods result in $14.1 million per year in average annualized losses to the state.

USGS, South Dakota Department of Transportation, and other state and federal agencies published a study in June 2012 titled "Extreme Floods in the Black Hills Area: New Insights from Recent Research." One of the most significant findings of the study is that massive floods as large as or larger than the 1972 flood have occurred multiple times over the past millennium in many drainage basins of the eastern Black Hills. According to the study, geologic evidence indicates that 12 floods exceeding 66,000 cfs occurred in the past 2,000 years, with the largest one occurring 440 years ago. The study found that "the steep terrain and narrow canyons along the eastern periphery of the Black Hills are most susceptible to flash flooding. Here the thin rocky soils absorb little rainfall, and the steep slopes cause rapid runoff into the stream channels. The steep and narrow canyons further amplify ferociously fast and deep floods." Figure 3-9 depicts the areas of the Black Hills with the highest and lowest potential for flash flooding based on the USGS/SDDOT study.

Climate Change Considerations

The nature and frequency of flooding could be altered by climate change, but at this point in time it is difficult to quantify. Heavy precipitation events that lead to flooding occur at the short-term time scales of weather, rather than the multi-year time scales of climate that most climate models examine. However, extreme events are, by their very nature, uncommon. Quantifying trends at a given location is quite difficult, and no trends in the historical record of extreme climate events have been definitively detected in South Dakota. Globally, higher temperatures will result in increased atmospheric water vapor available to form precipitation. Precipitation extremes and their hydrological impacts (e.g. floods) are expected to become larger because in most places. There is no comprehensive assessment of how climate change might affect flooding in the state, but regional trends for the northern Great Plains based on the National Climate Assessment indicates a trend toward less frequent, but more intense rain events. In this scenario rainy days would become less frequent, but if conditions are right for an extreme event, and more moisture is available in the atmosphere, then larger, extreme events are possible. The 100-year flood (or 1% annual chance flood) of today might become a more frequent event in the future (i.e., a 50-year event or 2% annual chance flood), meaning that current design levels and regulatory practices might be less adequate in the future. A 2013 report 'The Impact of Climate Change and Population Growth on the National Flood Insurance Program Through 2100' (AECOM 2013) suggests that special flood hazard areas will increase nationally, on average, by 40%-50% by 2100 as a result of climate change and in some areas, increased urbanization.

Figure 3-9 Generalized Potential for Flash Flooding in the Black Hills Area (modified from Driscoll and others, 2010)



Source: Driscoll, Huft, and O'Connor, *Extreme Floods in the Black Hills Area: New Insights from Recent Research*, 2012

Summer Storm

Description

Summer storms are not limited to one area of the state, and historically occur from early spring to early fall. Summer storms can include high winds, heavy rains and flooding, lightning and hail; they can also spur the development of funnel clouds and tornadoes. They can vary in intensity from mild to severe, and can cause injury or death, destroy property and kill livestock. Winds, flooding and tornadoes are discussed further in other chapters. This chapter covers two types of hazards caused by summer storms:

- Hail
- Lightning

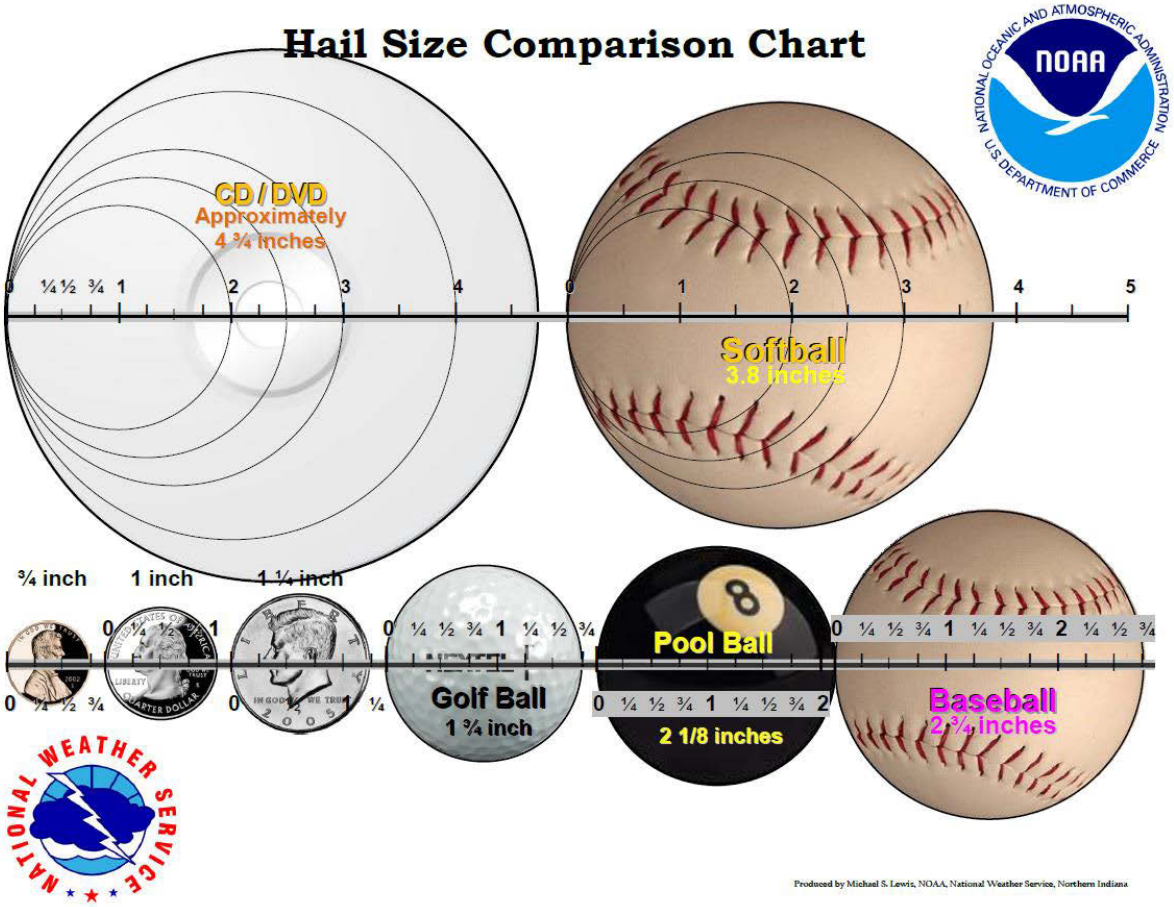
Hail

Hail is formed when water droplets freeze and thaw as they are thrown high into the upper atmosphere by the violent internal forces of thunderstorms. Hail is sometimes associated with severe storms within the Santa Fe County Planning Area. Hailstones are usually less than two inches in diameter and can fall at

speeds of 120 miles per hour (mph). Severe hailstorms can be quite destructive, causing damage to roofs, buildings, automobiles, vegetation, and crops.

Hail diameter is usually referenced in accordance with everyday objects; a hail size comparison chart is presented below in both visual and table form.

Figure 3-10 NOAA Hail Size Comparison Chart



Source: National Weather Service

Table 3-11: Hail Size Description Chart

Hailstone Size	Measurement	
	Inches	Centimeters
BB	< 0.25	<0.64
Pea	0.25	0.64
Dime	0.70	1.8
Penny	0.75	1.9
Nickel	0.88	2.2

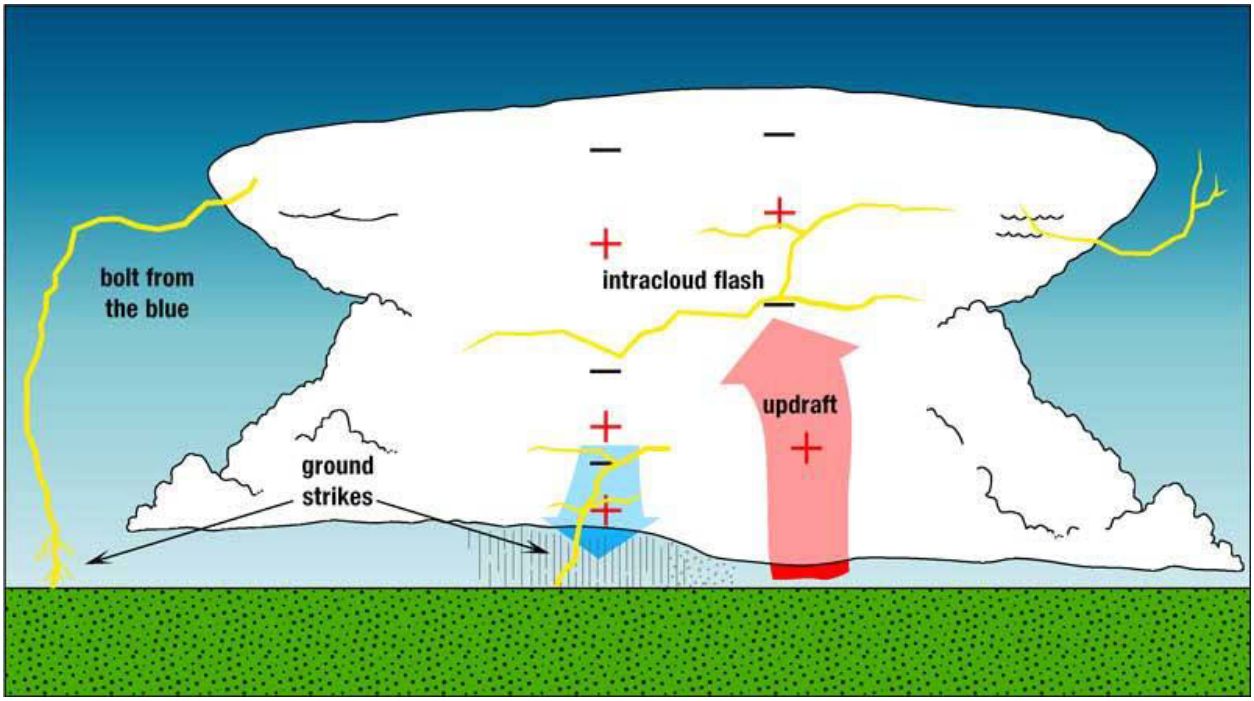
Quarter	1	2.5
Half Dollar	1.25	3.2
Golf Ball	1.75	4.4
Billiard Ball	2.13	5.4
Tennis Ball	2.5	6.4
Baseball	2.75	7
Softball	3.8	9.7
Compact Disc	4.75	12.1

Lightning

Lightning is defined as any and all of the various forms of visible electrical discharge caused by thunderstorms. Thunderstorms and lightning are usually (but not always) accompanied by rain. Cloud-to-ground lightning can kill or injure people by direct or indirect means. Objects can be struck directly, which may result in an explosion, burn, or total destruction. Damage may also be indirect, when the current passes through or near an object, which generally results in less damage.

Cloud-to-ground lightning is the most damaging and dangerous type of lightning. Most flashes originate near the lower-negative charge center and deliver negative charge to earth. However, a large minority of flashes carry positive charge to earth. These positive flashes often occur during the dissipating stage of a thunderstorm's life. Positive flashes are also more common as a percentage of total ground strikes during the winter months. This type of lightning is particularly dangerous for several reasons. It frequently strikes away from the rain core, either ahead or behind the thunderstorm. It can strike as far as 5 or 10 miles from the storm in areas that most people do not consider to be a threat. Positive lightning also has a longer duration, so fires are more easily ignited. And, when positive lightning strikes, it usually carries a high peak electrical current, potentially resulting in greater damage.

Figure 3-11 Cloud to Ground Lightning



Source: National Weather Service

Location

Summer storms can occur anywhere across the state due, though the higher elevations of the black hills have more potential for lightning strikes. More location information is in the following section on past events and Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction.

Past Events

According to the National Climatic Data Center (NCDC) South Dakota has experienced 10,502 separate hail incidents between 1996 and May 2016. It is important to note that these incidents may be separate impact areas caused by the same storm; it is also important to note that while NCDC is the best available free source for data on hazard impacts, the data can sometimes be imperfect.

NCDC data shows that the hail caused $160,637,750 in property damage and $42,775,000 in crop damage over this time period. The NCDC records 38 injuries and no fatalities caused by hail over this same timeframe. The following table analyzes the percentage of these incidents that caused recorded impacts.

Table 3-12: Impacts by Incident-Hail

Impact	Total	Number of Incidents w/ Impact	Percentage of Incidents with Recorded Impacts
Property Damage	$160,637,750	500	4.7%
Crop Damage	$42,775,000	70	.67%
Injuries	38	12	.11%
Fatalities	0	N/A	N/A

The following table lists recorded hail incidents by county between 1996 and 2016. The Top Five counties for recorded hail incidents are Pennington (807), Meade (510), Custer (411), Lawrence (307), and Minnehaha (299).

Table 3-13: Number of Hail Incidents by County (1996-2016)

County	Total Listed Events	Total Cumulative Damage
Aurora	111	$465,000
Beadle	170	$125,000
Bennett	144	$2,087,000
Bon Homme	149	$425,000
Brookings	107	$9,430,000
Brown	241	$0
Brule	117	$7,140,000
Buffalo	62	$0
Butte	173	$4,532,000
Campbell	95	$0
Charles Mix	179	$4,721,000
Clark	156	$0
Clay	116	250,000
Codington	145	$0
Corson	220	$0
Custer	411	$4,556,000
Davison	128	$5,050,000
Day	127	$0
Deuel	60	$0
Dewey	157	$0
Douglas	56	$1,275,000
Edmunds	194	$0
Fall River	210	$2,713,250
Faulk	119	$0
Grant	87	$0

Gregory	169	$4,960,000
Haakon	142	$160,500
Hamlin	121	$0
Hand	226	$0
Hanson	74	$65,000
Harding	226	$250,500
Hughes	114	$0
Hutchinson	105	$7,391,000
Hyde	94	$0
Jackson	201	$1,127,500
Jerauld	80	$2,285,000
Jones	78	$0
Kingsbury	118	$3,506,000
Lake	104	$1,560,000
Lawrence	307	$5,763,000
Lincoln	127	$4,200,000
Lyman	145	$0
Marshall	121	$0
McCook	118	$135,000
McPherson	129	$0
Meade	510	$3,664,500
Mellette	104	$170,500
Miner	78	$110,000
Minnehaha	299	$28,361,000
Moody	92	$1,675,000
Oglala Lakota	216	$611,000
Pennington	807	$67,584,000
Perkins	203	$2,051,000
Potter	79	$0
Roberts	79	$0
Sanborn	83	$2,747,000
Spink	152	$0
Stanley	119	$0
Sully	106	$0
Todd	171	$573,000
Tripp	180	$740,000
Turner	132	$2,351,000
Union	112	$581,000
Walworth	107	$0
Yankton	177	$17,270,000
Ziebach	162	$751,000

Source: NCDC

Figure 3-12 South Dakota Hail Events 1996 – May 2016

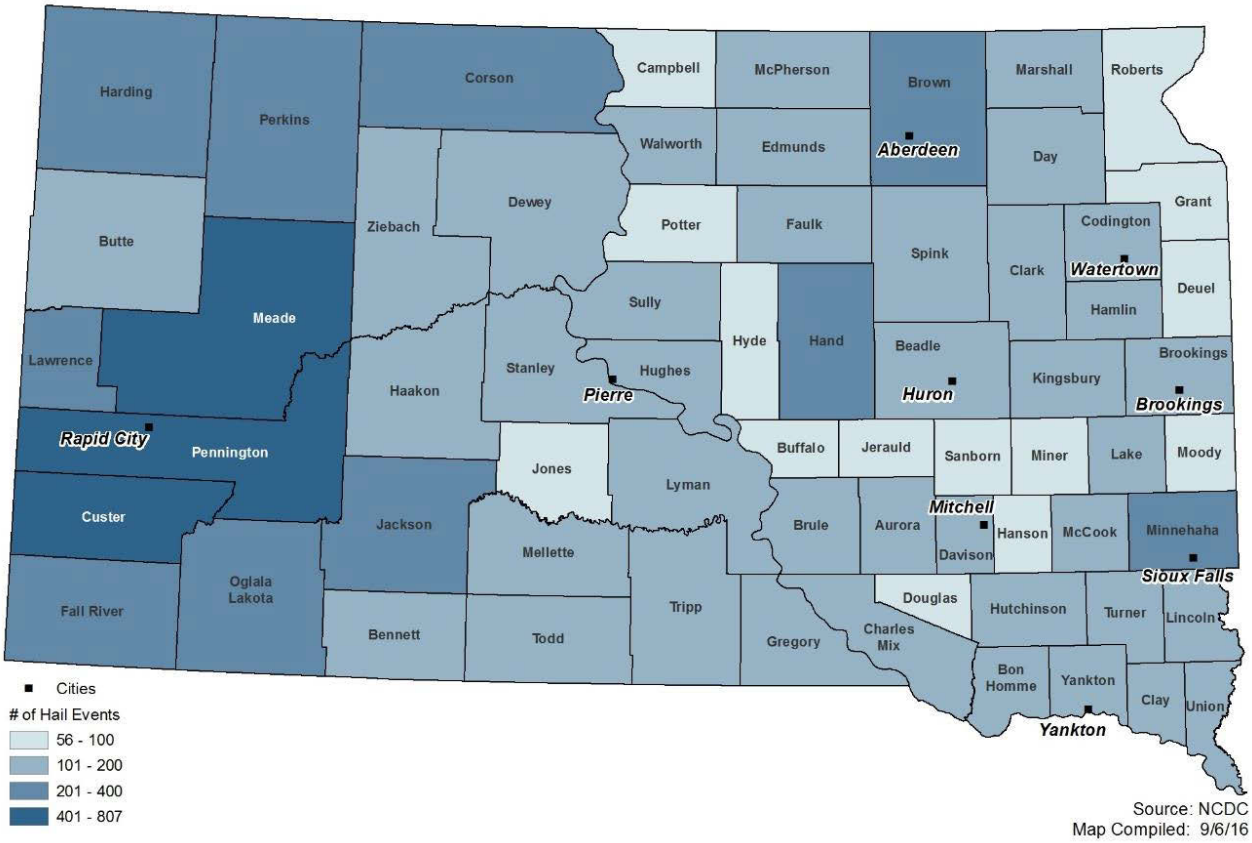


Table 3-14 shows selected hail incidents by hail size.

Table 3-14: Selected South Dakota Hail Events

County	Area	Date	Hail Size (Inches)	Deaths	Injuries	Property Damage	Crop Damage
Lyman Co.	Vivian	7/23/2010	8	0	5	$0	$0
Charles Mix Co.	Dante	8/21/2007	6.88	0	0	$0	$0
Charles Mix Co.	Wagner	8/21/2007	6.13	0	0	$0	$0
Butte Co.	Nisland	6/19/2015	6	0	0	$25000	$0
Minnehaha Co.	Hartford	7/13/1997	4.5	0	0	$20,00,000	$2,000,000
Meade Co.	Piedmont	6/1/2015	4.5	0	0	$500,000	$0
Kingsbury Co.	Lake Preston	7/28/2002	4.5	0	0	$100,000	$0
Lawrence Co.	St. Onge	6/19/2015	4.5	0	0	$10,000	$0

Meade Co.	Howes	6/26/1998	4.5	0	1	$0	$0
Faulk Co.	Faulkton	8/4/2000	4.5	0	0	$0	$0
Fall River Co.	Oelrichs	6/12/2001	4.5	0	0	$0	$0
Brown Co.	Barnard	6/23/2002	4.5	0	0	$0	$0
Mcpherson Co.	Leola	7/9/2002	4.5	0	0	$0	$0
Meade Co.	Elm Springs	8/26/2002	4.5	0	0	$0	$0
Lyman Co.	Presho	6/11/2003	4.5	0	0	$0	$0
Butte Co.	Newell	6/19/2015	4.5	0	0	$0	$0
Pennington Co.	Rapid City	8/3/2007	4.25	0	0	$500,000	$0
Pennington Co.	Johnson Siding	8/30/2013	4.25	0	0	$500,000	$0
Todd Co.	Rosebud	7/13/2009	4.25	0	0	$200,000	$0
Todd Co.	St Francis	3/18/2012	4.25	0	0	$100,000	$0
Fall River Co.	Edgemont	6/22/2012	4.25	0	0	$100,000	$0
Oglala Lakota Co.	Oglala	8/17/2014	4.25	0	0	$100,000	$0
Fall River Co.	Angostura Reservoir	5/24/2010	4.25	0	0	$40,000	$0
Custer Co.	Fairburn	6/21/2013	4.25	0	0	$25,000	$0
Todd Co.	Lakeview	7/20/2005	4.25	0	0	$20,000	$0
Harding Co.	Camp Crook	7/22/2011	4.25	0	0	$10,000	$0
Meade Co.	Faith	6/7/2005	4.25	0	0	$5,000	$0
Sully Co.	Agar	8/24/2006	4.25	0	0	$0	$0
Douglas Co.	Delmont	9/16/2006	4.25	0	0	$0	$0
Aurora Co.	White Lake	6/21/2007	4.25	0	0	$0	$0
Aurora Co.	White Lake	6/21/2007	4.25	0	0	$0	$0
Sully Co.	Clifton	6/21/2007	4.25	0	0	$0	$0
Sully Co.	Clifton	6/21/2007	4.25	0	0	$0	$0
Turner Co.	Center Pt	5/1/2008	4.25	0	0	$0	$0
Custer Co.	Hermosa	6/1/2008	4.25	0	0	$0	$0
Brown Co.	Westport	7/17/2010	4.25	0	0	$0	$0
Lyman Co.	Vivian	7/23/2010	4.25	0	0	$0	$0
Butte Co.	Belle Fourche	7/5/1998	4	0	3	$3,000,000	$0
Lake Co.	Countywide	7/11/2000	4	0	0	$500,000	$1,000,000
Custer Co.	Buffalo Gap	5/24/2010	4	0	0	$75,000	$0
Meade Co.	Piedmont	6/14/1997	4	0	0	$0	$0
Hughes Co.	Pierre	6/30/1997	4	0	0	$0	$0
Roberts Co.	Wilmot	7/19/1997	4	0	0	$0	$0
Pennington Co.	Wall	8/2/1997	4	0	0	$0	$0
Oglala Lakota Co.	Oglala	6/4/1999	4	0	0	$0	$0
Butte Co.	Belle Fourche	6/25/2007	4	0	0	$0	$0
Bon Homme Co.	Avon	8/8/2009	4	0	0	$0	$0
Davison Co.	Betts	8/8/2009	4	0	0	$0	$0

Spink Co.	Spink Colony	6/21/2013	4	0	0	$0	$0
Spink Co.	Spink Colony	6/21/2013	4	0	0	$0	$0

While not as prominent as hail, NCDC records 113 lightning incidents between 1996 and 2016. The recorded lightning strikes caused $2,171,200 in property damage and no recorded crop damage; five fatalities and 17 injuries were attributed to these events. The following table presents lightning incidents in the state that had some level of recorded impact – the incident caused damages, injuries or fatalities.

Table 3-15: South Dakota Lightning Events 1996-2016

County	Area	Date	Deaths	Injuries	Property Damage	Crop Damage
Lake Co.	Chester	5/7/1996	0	0	$1,000	$0
Kingsbury Co.	Lake Preston	5/18/1996	0	0	$2,000	$0
Douglas Co.	Armour	7/6/1996	0	0	$10,000	$0
Bon Homme Co.	Springfield	8/6/1996	0	0	$10,000	$0
Lincoln Co.	Sioux Falls	10/16/1996	0	0	$20,000	$0
Davison Co.	Mitchell	7/16/1997	0	0	$1,000	$0
Fall River Co.	Edgemont	7/23/1997	0	0	$5,000	$0
Davison Co.	Mitchell	7/24/1997	0	0	$4,000	$0
Clay Co.	Vermillion	7/27/1997	0	0	$20,000	$0
Minnehaha Co.	Brandon	9/8/1997	0	0	$20,000	$0
Lincoln Co.	Beresford	5/15/1998	0	0	$40,000	$0
Bon Homme Co.	Running Water	6/17/1998	0	0	$20,000	$0
Pennington Co.	Rochford	7/8/1998	0	1	$0	$0
Beadle Co.	Huron	7/18/1998	0	0	$10,000	$0
Moody Co.	Flandreau	7/18/1998	0	0	$5,000	$0
Brookings Co.	Volga	7/20/1998	0	0	$5,000	$0
Hutchinson Co.	Parkston	8/5/1998	0	1	$0	$0
McCook Co.	Bridgewater	8/23/1998	0	0	$10,000	$0
Kingsbury Co.	De Smet	6/4/1999	0	0	$2,000	$0
Todd Co.	Parmelee	8/11/1999	0	1	$0	$0
Marshall Co.	Langford	8/12/1999	0	0	$50,000	$0
Lake Co.	Madison	5/17/2000	0	0	$1,000	$0
Moody Co.	Colman	6/3/2000	0	0	$70,000	$0
Minnehaha Co.	Sioux Falls	6/25/2000	0	0	$100,000	$0
Brookings Co.	Bruce	7/9/2000	0	0	$5,000	$0
Lawrence Co.	Lead	7/27/2000	0	0	$5,000	$0
Brookings Co.	Elkton	4/22/2001	0	0	$80,000	$0
Minnehaha Co.	Sioux Falls	4/22/2001	0	0	$20,000	$0
Minnehaha Co.	Sioux Falls	4/22/2001	0	1	$5,000	$0
Oglala Lakota Co.	Pine Ridge	6/9/2001	1	1	$1,000	$0

Pennington Co.	Sheridan Lake	6/24/2001	1	2	$0	$0
Yankton Co.	Yankton	7/7/2001	0	0	$10,000	$0
Charles Mix Co.	Lake Andes	7/7/2001	0	0	$1,000	$0
Brookings Co.	Brookings	7/22/2001	0	0	$3,000	$0
Brookings Co.	Brookings	7/22/2001	0	0	$3,000	$0
Bon Homme Co.	Avon	7/30/2001	0	0	$5,000	$0
Aurora Co.	Plankinton	7/30/2001	0	0	$1,000	$0
Custer Co.	Custer	8/1/2001	0	0	$500,000	$0
Brookings Co.	Brookings	5/7/2002	0	0	$5,000	$0
Moody Co.	Flandreau	6/10/2002	0	0	$5,000	$0
Kingsbury Co.	De Smet	7/28/2002	0	0	$10,000	$0
Brule Co.	Kimball	8/8/2002	0	0	$20,000	$0
Kingsbury Co.	Arlington	8/12/2002	0	0	$2,000	$0
Minnehaha Co.	Sioux Falls	9/19/2002	0	0	$20,000	$0
Beadle Co.	Huron	5/29/2003	0	0	$5,000	$0
Beadle Co.	Huron	5/29/2003	0	0	$5,000	$0
Lincoln Co.	Hudson	7/3/2003	0	0	$5,000	$0
Pennington Co.	Rapid City	7/8/2003	0	1	$0	$0
Yankton Co.	Midway	7/20/2003	1	1	$0	$0
Union Co.	Elk Pt	4/21/2004	0	1	$2,000	$0
Miner Co.	Howard	5/21/2004	0	0	$20,000	$0
Todd Co.	Okreek	6/8/2004	0	0	$500,000	$0
Beadle Co.	Hitchcock	8/1/2004	0	0	$5,000	$0
Hanson Co.	Alexandria	8/3/2004	0	0	$50,000	$0
Yankton Co.	Yankton	8/22/2004	0	0	$2,000	$0
Brule Co.	Bijou Hills	8/23/2004	0	0	$20,000	$0
Davison Co.	Mitchell	8/31/2004	0	0	$10,000	$0
Davison Co.	Mitchell	9/4/2004	0	0	$2,000	$0
Kingsbury Co.	De Smet	5/7/2005	0	0	$200,000	$0
Lake Co.	Madison	6/29/2005	0	0	$200	$0
Minnehaha Co.	Sioux Falls	7/7/2005	0	0	$10,000	$0
Grant Co.	Milbank	8/10/2007	0	0	$2,000	$0
Hughes Co.	Pierre	6/5/2008	0	0	$50,000	$0
Minnehaha Co.	East Sioux Falls	7/31/2008	0	2	$0	$0
Meade Co.	Sturgis	8/5/2008	0	3	$0	$0
Brookings Co.	Brookings	5/4/2009	0	0	$5,000	$0
Lincoln Co.	Tea	6/23/2009	0	0	$30,000	$0
Moody Co.	Colman	9/30/2009	0	0	$1,000	$0
Yankton Co.	Yankton	7/11/2010	0	0	$5,000	$0
Moody Co.	Flandreau	5/10/2011	0	0	$20,000	$0
Pennington Co.	Rapid City	6/24/2011	0	0	$6,000	$0

Pennington Co.	Wasta	8/3/2011	1	0	$0	$0
Custer Co.	Buffalo Gap	5/27/2014	0	1	$0	$0
Brown Co.	Aberdeen	6/5/2014	0	0	$2,000	$0
Pennington Co.	Rockerville	6/4/2015	0	0	$2,000	$0
Pennington Co.	Rapid City	6/20/2015	0	0	$50,000	$0
Lawrence Co.	Spearfish	7/12/2015	1	1	$0	$0
Lincoln Co.	South Sioux Falls	8/27/2015	0	0	$5,000	$0
Lincoln Co.	Tea	8/27/2015	0	0	$5,000	$0
McCook Co.	Salem	5/25/2016	0	0	$45,000	$0

Source: NCDC

The following table analyzes the percentage of these incidents that caused impacts.

Table 3-16: Impacts by Incident-Lightning

Impact	Total	Number of Incidents w/ Impact	Percentage of Incidents with Impact
Property Damage	$2,171,200	69	61%
Crop Damage	0	N/A	N/A
Injuries	17	13	11%
Fatalities	5	5	4.3%

Source: NCDC

See Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction for more information about how lightning and hail affect individual counties.

Probability

According to the National Climatic Data Center Storm Events database, there were 10,501 hail incidents in South Dakota between January 1996 and May 2016. The average hail stone size for these incidents was a little over 1 inch in diameter, though hail up to eight inches in diameter was recorded in Vivian in Lyman County in July 2010. This suggests that South Dakota experiences 525 separate hail incidents on average annually. Zero deaths and 38 injuries were attributed to these events. Based on past history, South Dakota can expect few if any deaths, and almost 1-2 injuries each year caused by hail.

Based on this information, the probability that multiple hail storms will occur in South Dakota in any given year is 100 percent.

Lightning is a common event that occurs in almost every thunderstorm in the state. Most lightning is harmless to those on the ground, bouncing from cloud to cloud. However, when lightning does strike a target on the ground, it can do tremendous damage to people and property. Between 1996 and 2016, NCDC recorded 114 separate lightning strikes, or almost six per year. Cumulatively, these storms caused five deaths and seventeen injuries. Extrapolated into the future, the State of South Dakota can expect damaging lightning strikes annually; based on NCDC-recorded data, these strikes will cause one recorded injury every other year, and a lightning-caused fatality every four years. T

Climate Change Considerations

NASA's Earth Observatory provides an analysis on how climate change could, theoretically, increase potential storm energy by warming the surface and putting more moisture in the air through evaporation. The presence of warm, moist air near the surface is a key ingredient for summer storms that meteorologists have termed "convective available potential energy," or CAPE. With an increase in CAPE, there is greater potential for cumulus clouds to form. The study also counters this theory with the theory that warming in the Arctic could lead to less wind shear in the mid-latitude areas prone to summer storms, making the storms less likely. Based on these differing theories it is difficult at this point in time to summarize the effects climate change may have on summer storms.

Winter Storm

Description

Winter storms are not limited to one area of the state and historically occur from late fall to the middle of spring. They vary in intensity from mild to severe. Winter storms regularly destroy property and kill livestock. They can immobilize a region, blocking roads and railways and closing airports, which can disrupt emergency and medical services, hamper the flow of supplies, and isolate homes and farms, possibly for days. Heavy snow can collapse roofs and knock down trees and power lines. Unprotected livestock may be lost. Economic impacts include cost of snow removal, damage repair, and business losses.

The National Weather Service describes different types of snow events as follows:

- Blizzard—Winds of 35 mph or more with snow and blowing snow reducing visibility to less than ¼ mile for at least 3 hours.
- Blowing Snow—Wind-driven snow that reduces visibility. Blowing snow may be falling snow and/or snow on the ground picked up by the wind.
- Snow Squalls—Brief, intense snow showers accompanied by strong, gusty winds. Accumulation may be significant.
- Snow Showers—Snow falling at varying intensities for brief periods of time. Some accumulation is possible.
- Snow Flurries—Light snow falling for short durations with little or no accumulation.

Also associated with winter storms are ice, freezing rain, and sleet. Freezing rain coats objects with ice. This ice coating on sidewalks, roads, etc., creates dangerous conditions. Sleet does not generally cling to objects like freezing rain, but it does make the ground very slippery. Heavy accumulations of ice can bring down trees and topple utility poles and communication towers. Ice can disrupt communications and power for days while utility companies repair extensive damage. Even small accumulations of ice can be extremely dangerous to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces.

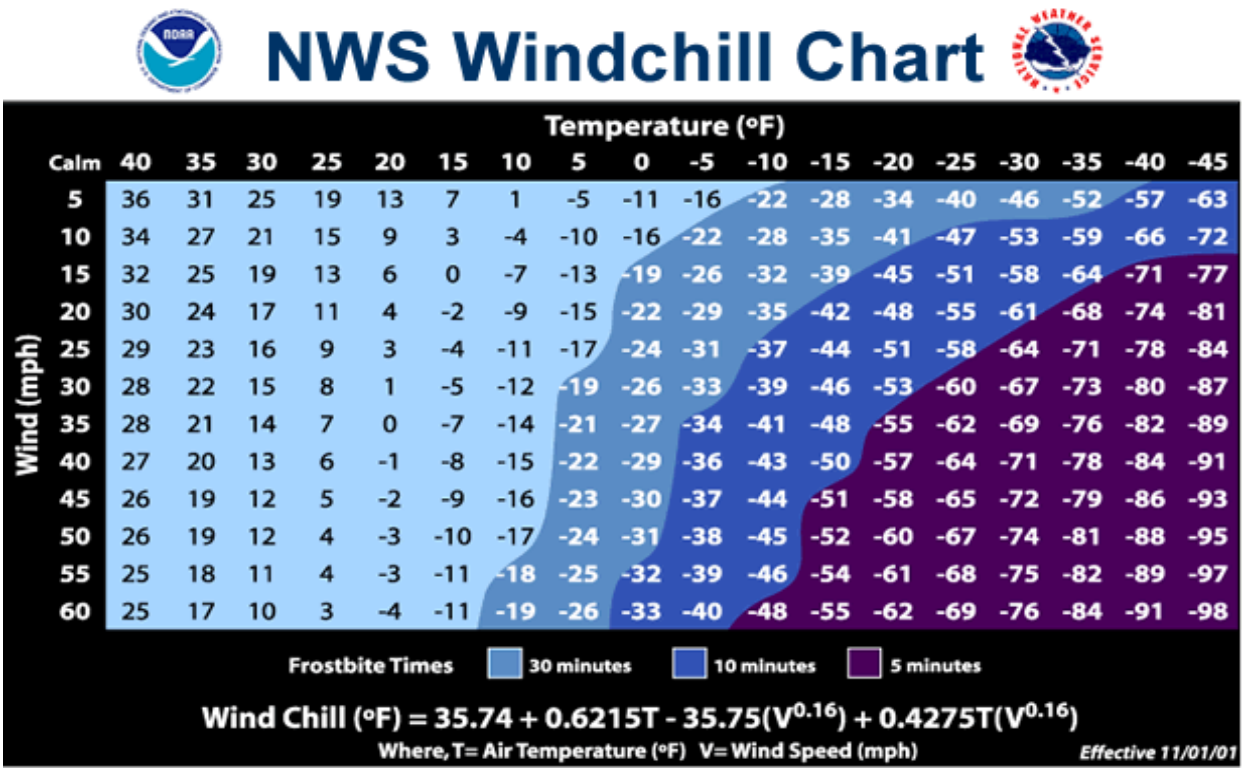
Winter storms can also generate flooding, usually as a result of ice jams or snowmelt, which can cause significant damage and loss of life. Ice jams form when long cold spells cause rivers and lakes to freeze and a rise in water level or a thaw breaks the ice into large chunks that become jammed at obstructions

(e.g., a bridge). Water backs up at the jam, which is acting as a dam, and flooding results. The snowmelt hazard is defined as a sudden thaw of a heavy snow pack that often leads to flooding. Both snowmelt and ice jam floods are common in South Dakota.

Extreme cold often accompanies a winter storm or is left in its wake. It is most likely to occur in the winter months of December, January, and February. Prolonged exposure to the cold can cause frostbite or hypothermia and can become life-threatening. Infants and the elderly are most susceptible. Pipes may freeze and burst in homes or buildings that are poorly insulated or without heat. Extreme cold can disrupt or impair communications facilities.

In 2001, the NWS implemented an updated Wind Chill Temperature index (see Figure 3-13). This index was developed to describe the relative discomfort/danger resulting from the combination of wind and temperature. Wind chill is based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature.

Figure 3-13 National Weather Service Wind Chill Chart



Wind (mph) \ Temperature (°F)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Source: National Weather Service

Location

Winter storm has an even probability across the state due to its topography. The inherent nature of temperature hazards makes them a regional threat, impacting most or all of the planning area simultaneously as well as extending the effects into the surrounding jurisdictions. Prairie lands, which cover most of the state, offer little resistance to high winds and drifting snow. Even the Black Hills region, which presents some resistance to wind conditions, is not excluded from blizzard conditions.

Blizzards in this region are often less severe than elsewhere in the state, but they can still produce heavy drifting snows. Early blizzards were so devastating that South Dakota had the dubious distinction of being called the Blizzard State.

According to the National Weather Service, most of South Dakota has an annual mean snowfall of 24.1 to 36 inches. Some areas in the northeast, northwest, and southwest have an annual mean snowfall of 36.1 to 48.0 inches, and a small area in the southwest has an annual mean snowfall greater than 72 inches.

More location information is in the following section on past events and Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction.

Past Events

According to the National Climatic Data Center Storm Events database, there were 1,971 winter storms (snow and ice events) in South Dakota between January 1993 and March 2016, and 477 extreme cold events from January 1994 to March 2016. Total property damage for these events is estimated at $91 million dollars. This suggests that South Dakota experiences 85 winter storms and $4 million in winter storm losses annually, as well as 20 extreme cold events each year. 12 deaths and 127 injuries were attributed to these events. This suggests that South Dakota can expect approximately 1 death every other year and 6 injuries each year. South Dakota's agricultural industry is also very susceptible to losses from winter weather and extreme cold.

See Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction for more information about how winter storms affect individual counties.

Figure 3-14 South Dakota Winter Storm Events 1993 – May 2016

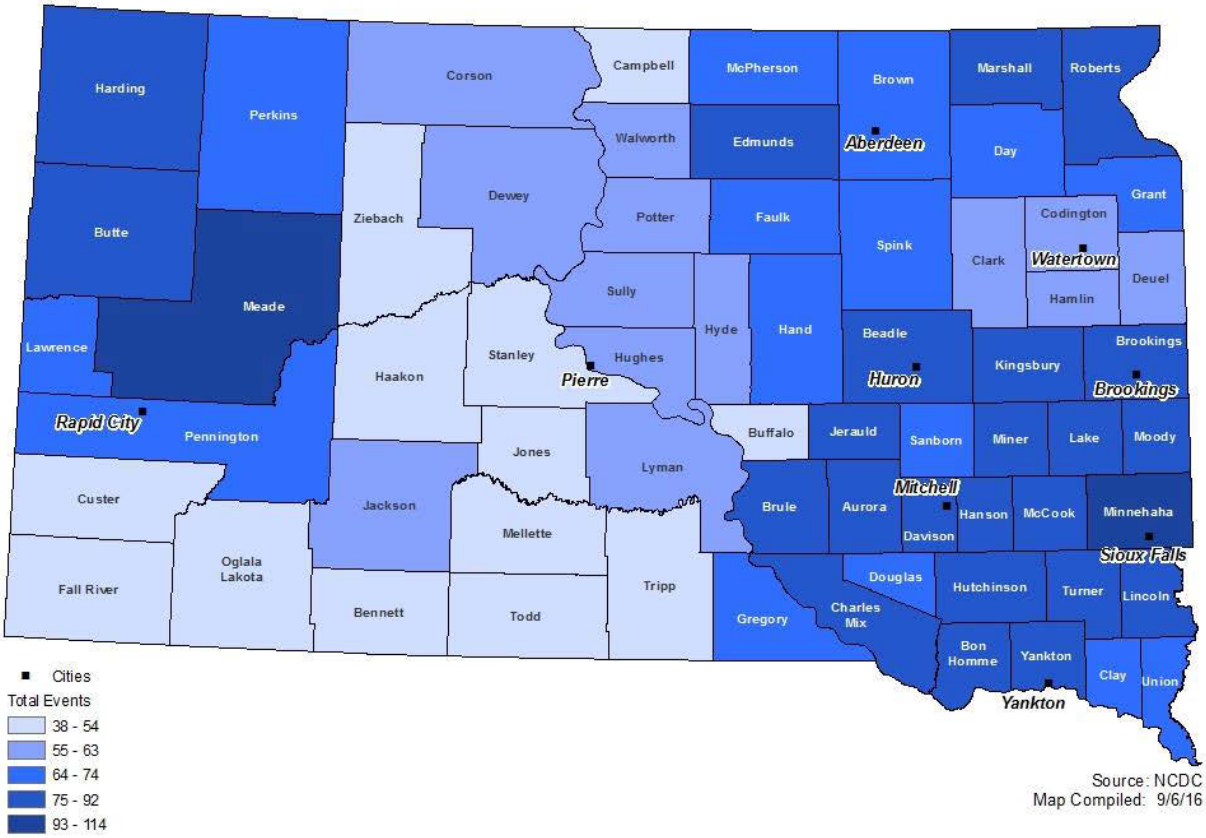


Table 3-17: South Dakota Winter Storm Events

Date	Comments
April 8-10, 2013	**Severe Winter Storm and Snowstorm (FEMA-4115-DR)** A large spring snowstorm dumped heavy snow over most of western South Dakota April 8-10, 2013. The final NWS storm report showed that Deadwood received 30 inches of snow during the storm and Rapid City received 28.2 inches for some of the highest snowfalls in the State. April 2013 ended up being the snowiest month on record for South Dakota with 39.5 inches total, beating the previous record of 38.5 inches set in April 1927. This storm resulted in a major disaster declaration for seven counties.
January 17, 2011	Northwest winds caused blowing and drifting snow over an area which extended from Brookings County into southwest Minnesota. Cold temperatures and wind chills approaching 20 degrees below zero developed during the event and continued through the night as the winds and blowing snow slowly decreased. There was a fatality from exposure in Brookings County during the event. A 65 year old woman died of exposure after she left her vehicle which had become stuck in drifts on a township road near Elkton.
January 9,	Snow produced heavy accumulations of 8 to 10 inches in an area near the Missouri River in southeast South Dakota during a 24 hour period beginning in the late

Date	Comments
2011	afternoon of January 9th. Lesser accumulations of 4 to 8 inches were reported further north and west in southeast South Dakota. An exposure fatality was reported in Sioux Falls during the snowfall. A 70 year old woman died after wandering away from her assisted living facility at night. Wind chills at the time varied from zero to 5 above.
December 23, 2010	An upper level disturbance passed over the region during the night and early morning, bringing milder air over cold air at the surface. Light freezing rain developed over western South Dakota, mixing with snow and sleet at times. The heaviest freezing rain fell across southwestern South Dakota, including the Black Hills, where as much as a quarter inch of ice accumulated. Roads became ice covered and caused many accidents during the morning. A total of $475,000 in damages (2010$) resulted from this event. NCDC did not record any injuries or fatalities.
December 10, 2010	Snowfall ranging from 2 to 8 inches was accompanied by sustained northwest winds which reached 40 mph at times, with gusts as high as 55 mph. The snowfall, strong winds, and existing snow cover resulted in widespread blizzard conditions. Travel was made impossible in much of the area. There were several accidents and vehicles going into ditches, attributed to slick roads and low visibilities. Several motorists were stranded. Businesses were forced to close, and several school and other weekend activities were canceled or postponed.
April 2, 2010	**Severe Winter Storm (FEMA-1914-DR)** The April 2, 2010, blizzard caused an estimated $1.6 million in damage in the three-county area. A band of heavy snow set up across Corson and Dewey counties during the early morning hours of April 2nd. Along with heavy wet snow, northwest winds gusting up to 40 mph developed. By the time the snow ended in the late morning hours, 6 to 8 inches of snow had fallen. The heavy snow, combined with the strong winds, downed many power poles across the region along with making travel treacherous. Some snowfall amounts included; 4 inches at Eagle Butte; 6 inches at Timber Lake, McLaughlin, and 14 miles north of Isabel; 7 inches at Isabel and 6 miles southeast of McIntosh; 8 inches southwest of Keldron. Heavy snow and strong winds knocked down power lines and poles, cutting off electricity to more than 1,500 rural electric customers. More than 400 poles were lost to the heavy snow leaving approximately 800 people without power. Eighty linemen worked through the Easter weekend in the snow and mud. McLaughlin and Keldron were the hardest hit. Several hundred people were still without power on April 5th. Corson, Perkins, and Ziebach Counties were also among those struck by a late-January ice storm that qualified them for an earlier Presidential Disaster Declaration. Some of the power lines damaged by the April storm had just been repaired from damage caused by the January ice storm.
January 20-26, 2010	**Severe Winter Storm (FEMA-1887-DR)** A powerful storm struck the northeast half of the state. The storm began with rain, turning to sleet, followed by heavy snow. Winds of up to 60 mph accompanied the storm. Power lines burdened by ice after several days of heavy fog began snapping and falling. FEM Electric lost over 4,300 utility poles in Edmunds, Faulk, McPherson, and Potter counties. Customers of 1,600 meters were without power for 13 days. One customer was poisoned from inhaling generator exhaust. FEM Electric's business and economic impacts were estimated at $40,000,000, while emergency repair and restoration costs were estimated at $10,000,000. High winds

Date	Comments
	and blizzard conditions across the eastern and north central regions of the state stalled traffic and further complicated relief efforts. Interstate 90 was closed from Chamberlain to the Minnesota border. Interstate 29 was closed from Sioux Falls to the North Dakota border. An estimated 7,600 customers across South Dakota were without power. Some phone systems also experienced outages. At least 31 emergency shelters were open across the hard hit regions. Indian reservations were hit especially hard. The Cheyenne River Sioux Tribe had a breakdown at the water treatment plant as a result of the storm that left many residents without potable water.
December 23-27, 2009	**Severe Winter Storm (FEMA-1886-DR)** A powerful winter storm blanketed the entire state. The entire Interstate highway systems were shut down for an extended period across South Dakota. Winds gusted as high as 76 mph in western South Dakota Preliminary storm totals from the State Climatologist across the state from the Christmas blizzard indicated that the large majority of the state received over 10" of snow in the storm with 20" or greater amounts in the southeast (Marion-Vermillion-Yankton), northeast (Sisseton and Clear Lake), central (Kennebec and Murdo) and northwest (Perkins County). The northern Black Hills recorded 40-50". The statewide average was 15.4". This would place it as one of the top few storms for snowfall totals statewide.
March 23-34, 2009	A powerful spring storm brought rain, snow, and very strong winds to western South Dakota. Precipitation started as rain, then changed to snow, and blizzard conditions developed. The heaviest snow fell over the northern Black Hills, where 18 to 48 inches of snow was measured. Ten to 20 inches of snow fell across far northwestern South Dakota, with drifts as high as ten feet. Most other locations received at least six inches of snow. Sustained winds of 30 to 55 mph, with gusts over 80 mph, were reported. Interstate 90 and other highways were closed for more than 24 hours. Some power outages were reported, mainly across the northern Black Hills and northwestern South Dakota. Tens of thousands of livestock perished. Damage estimates were slated in the millions.
November 5-7, 2008	An intense fall storm brought heavy snow and gusty winds to much of the Black Hills. The heaviest snow fell across the northern Black Hills as upslope-enhanced snow fell for many hours. Snowfall amounts ranged from only a few inches across the southeastern slopes of the Black Hills to near five feet from Cheyenne Crossing to Lead and Deadwood in the northern Black Hills. The next day, a strong area of low pressure moving across South Dakota and into Minnesota brought widespread rain, freezing rain, and snow to central, north central, and northeast South Dakota. Much of the freezing rain fell across central and north central South Dakota west of the Missouri River. As the freezing rain changed over to snow and the winds increased, the ice and snow buildup on the power lines and poles caused hundreds of power poles to break across Jones, Stanley, Dewey, and Corson counties. East of the Missouri River, the colder air and stronger winds moved in changing the rain over to snow. Strong winds of 30 to 45 mph with gusts near 60 mph brought widespread blizzard conditions to all of the area. Ice buildup from the freezing rain ranged from a tenth to as much as an inch for counties west of the Missouri River. Snowfall amounts across the entire area generally ranged from 2 to 8 inches with a

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	15 inch amount recorded in southwest Corson County. Some of the snowfall amounts included: 3 inches at Eagle Butte, Blunt, Kennebec, Mission Ridge, and Onida; 4 inches at Pollock, Gettysburg, and Bowdle; 5 inches south of Harrold, Iona, and near McIntosh; 6 inches at Mobridge; 7 inches at Murdo; 8 inches at McLaughlin, and 15 inches southwest of Keldron. All 4,600 customers of the Moreau-Grand Electric company lost power due to the storm. The last time this occurred was during the winter of 1967-68. The monetary loss to this cooperative and other electric cooperatives for Jones, Stanley, Corson, and Dewey counties was in the hundreds of thousands of dollars. There were over 100 line workers working countless hours with crews coming from as far away as Nebraska and Iowa to assist in the power recovery. Over 1,000 customers were without power for an extended period of time. Cell phone coverage was also knocked out for parts of the West River area due to downed towers. The blizzard resulted in numerous school, business, and road closures along with flight cancellations. Interstate-90 was shut down from Mitchell, South Dakota to the Wyoming border from Thursday the 6th until Friday evening of the 7th. Many semi-trucks and cars were stranded along the Interstate with many people being rescued. Many travelers took shelter in Murdo, Chamberlain, and Pierre until the Interstate reopened Friday evening. There were also several accidents across the area with a serious accident in Walworth county on Highway 83 near the Potter county line. In the early afternoon hours of Friday the 7th, slippery roads, high winds, and low visibilities contributed to the rollover of a passenger van carrying seven students. The passenger van rolled several times causing serious injuries to three of the students. Also, a semi-truck rolled over on an icy and snowy Highway 45 south of Miller in the late afternoon hours of the 6th. The driver received minor injuries. The Governor declared a state of emergency on the 7th, and President Bush declared South Dakota a disaster area.
April 25-26, 2008	A strong low pressure area brought widespread heavy snow of 6 to 20 inches to most of northeast South Dakota for much of the 25th and into the early morning hours of the 26th. The precipitation began as light freezing rain in the early morning across parts of the area before changing to all snow by mid-morning. As the low pressure area intensified, snowfall rates and the north winds also increased. The heavy snow combined with the strong winds created widespread visibility problems along with large snowdrifts. Snowfall amounts included, 6 inches at Andover, Britton, Gann Valley, and 15 miles south of Miller, 8 inches at Roy Lake, 9 inches at Clark, Big Stone City, Hillside Colony, and Sisseton, 10 inches 7 miles south of Bristol, and 11 inches at Hayti. Locations with a foot or more of snowfall included, 12 inches at Wilmot, Webster, and Waubay, 13 inches at Milbank, 15 inches at Castlewood, 16 inches near Victor, and near Summit, 17 inches at Clear Lake, 19 inches at Watertown, and 20 inches at Bryant. There were a number of automobiles that went into the ditch along with many other automobiles damaged in accidents. Many stranded motorists had to abandon their vehicles in the hardest hit areas. Travel was not advised across the entire area. A school bus slid into a ditch east of Castlewood with no injuries occurring. Interstate-29 was closed from 3 pm the 25th until 3 pm on the 26th from Brookings north to the North Dakota border. In addition, South Dakota State Highway 12 was closed from Webster to the Minnesota line from the afternoon of the 25th until the late morning of the 26th. Most counties affected by the storm opened emergency shelters when Interstate 29

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	was closed to house stranded motorists. Also, many schools were closed across the area. The very heavy snow set several records across the area. The 19 inches at Watertown broke its all-time 24 hour snowfall record of 16 inches. Both Victor and Clear Lake had their second highest snowfall ever recorded in a 24 hour period. Watertown, along with several other locations in northeast South Dakota, received near record or record snowfall for the month of April. In fact, Watertown's 29.5 inches of snow for the month of April was almost their seasonal normal snowfall. This event was also declared a disaster by the President.
March 1, 2007	In southeast South Dakota, four to eight inches of snow was accompanied by sustained winds of over 30 mph at times with gusts over 40 mph. The combination of new snow, wind, and existing fresh snow cover resulted in a blizzard with widespread near zero visibilities. Drifting snow made travel extremely difficult to impossible. As a result, some who did attempt to travel became stuck or slid off roads. Schools and school activities were cancelled and numerous businesses closed. Source: National Climatic Data Center
April 18-20, 2006	**Severe Winter Storm (FEMA-1647-DR)** The strongest storm of the 2005-2006 winter brought heavy, wet snow to northwestern South Dakota and the Black Hills and heavy rain across southwestern and south central South Dakota. Reported snow totals included 10 to 24 inches in northwestern South Dakota, 16 to 30 inches in the Bear Lodge Mountains, 40 to 70 inches in the northern Black Hills, 74 inches in Lead, and 55 inches in Deadwood. Fifteen-foot drifts were reported on the plains of northwestern South Dakota. Source: NWS Rapid City
November 27-29, 2005	**Severe Winter Storm (FEMA-1620-DR)** This storm brought snow and ice to the state. It was one of the worst ice storms in the state's history. Snowfall accumulations in central South Dakota ranged from 2 to 20 inches. Strong northwest winds of 30 to 50 mph with gusts to 70 mph caused widespread blizzard conditions. Visibilities were reduced to zero across the area with snowdrifts of 5 to 10 feet high in some places. Freezing rain occurred before the snow in some areas coating objects with up to three inches of ice and causing power outages. Some power lines were also brought down by snow and ice accumulation and high winds. Tens of thousands of households and businesses lost power from one day to up to two to three weeks in some rural areas. One electric cooperative said it was the worst damage they had in their 65 years of existence. Bon Homme Yankton Electric Association had 455 broken poles, 82 cross arms, and numerous line breaks. 509 customers were affected. The last line was turned on 8 days after the start of the storm. Consumers experienced roughly 118.1 hours or 4.9 days without power. Emergency repair and restoration costs were estimated at $352,323 with $282,538 in federal and state disaster relief funding. Many roads, including Interstates 90 and 29 were closed due to the treacherous travel conditions. Several accidents occurred during the storm, killing two and injuring others. Many motorists were stranded. Several people had to be rescued. Air traffic was also brought to a halt across much of the area. Schools, businesses, government offices, and many other organizations were closed. Minor damage was caused to homes and vehicles by the strong winds and by windblown debris, mainly from trees. A 79-year old man died from exposure in Douglas County. Source: National Climatic Data Center and SHMT
April 2000	**Winter Storm (FEMA-1330-DR)**

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	From April 19-20, a severe spring storm consisting of rain, heavy snow, and very high winds struck seven western counties of South Dakota. The storm's greatest impact was on the electrical power system. One to three feet of heavy, wet snow coupled with ice and high winds caused significant damage to three rural electric cooperatives, resulting in widespread power outages to homes and businesses. The power providers reported that over 1,500 power poles were damaged or destroyed. Eligible damage to public infrastructure was estimated at approximately $2,500,000.
April 1997	An ice storm that affected Edmunds and McPherson counties damaged 400 utility poles and caused 1,500 wire breaks. FEM Electric customers on 600 meters were without power for seven days. Business and economic impacts of this storm were estimated at $3,000,000 and emergency repair and restoration costs were estimated at $1,000,000.
January 1997	**Severe Winter Storms/Blizzards (FEMA-1156-DR)** All counties were declared disaster areas. Twice in a seven-day period in early January, cold Arctic air swept down and "froze" the state. The governor closed the interstates for public safety. More than 36,000 head of cattle perished. Roads were blocked or covered by 20-foot drifts of snow. Fifteen days after the storm ended, some roads were still blocked by snow. The Day County highway superintendent reported 20- and 40-foot vertical drifts blocking the highway. Livestock losses, damaged buildings, and feed shortages occurred in an area called the "red zone." This is an area of 4,722 cattle operations, 1,200 sheep operations, 1,000 hog farms, and 515 dairies along the northern third of the state west to east. The storm caused more than $30 million in damage/cleanup efforts. Three people died while trapped in vehicles along the highways. The snowmelt from this record-breaking storm was a major contributor to the flood disaster a few months later.
December, 1996	Extreme cold struck portions of South Dakota. A Summit man died from exposure to the extreme cold after his vehicle became stuck in the snow. The man attempted to walk for help and was found about one mile from his car in the driveway of a home about a mile and a half west and one mile south of Summit.
November 13-26, 1996	A slow moving winter storm with severe snow and freezing rain entrenched itself over much of the state. The effects of the storm were felt primarily in the Black Hills and southeastern portions of the state. The storm was a result of a strong system of cold air, hovering close to the ground, with a system of warm air above. This combination made for rain, fog, and snow that quickly turned to damaging ice. The snow and ice formed and amassed on roadways, trees, electric transmission lines, and power poles. Some power lines were swollen by ice to five inches in diameter. The excessive weight and severe wind conditions snapped lines and flattened poles. Thousands of polebraces, crossarms, and anchors cracked under the heavy stress. Six rural electric cooperatives, affecting approximately 10,700 customers, experienced serious outages due to the loss of poles, braces, lines, crossarms, anchors, and substation failures. Customers were without power in subfreezing temperatures for several hours to several days. The force of the storm caused major delays on Interstates 90 and 29. Portions of state and county highways and roads were closed for an extended period of time due to heavy ice and snow accumulation and extremely poor visibility.
October 22-24, 1995	**Ice Storms (FEMA-1075-DR-SD)** Between October 22 and 24, 1995, a severe autumn snow and ice storm caused widespread damage in South Dakota. Effects of this storm were felt first in the

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	Black Hills. Portions of the hills received up to 22 inches of snow. As the storm moved across South Dakota, ice and 5 to 15 inches of wet snow covered trees and electric lines and poles. Winds associated with the storm caused lines to slap together and poles to fail, producing widespread power outages to large portions of rural South Dakota. Tree damage also led to significant damage to electrical utilities. Thirteen rural electric cooperatives reported damage from this storm. The cooperatives lost nearly 9,500 poles and 170 transmission lines. Damage was estimated at $10 to $10.3 million to rural electric infrastructure only. Approximately 30,290 households were affected by the power outages. Crews from electric cooperatives in South and North Dakota, Minnesota, Iowa, and Nebraska assisted local cooperatives with line repairs. The power outages also caused several rural water system pumping stations to go off-line, causing a loss of water utilities to members of rural water systems. The National Guard provided generators to power these pumping stations to restore water service. This storm also forced major transportation delays as portions of Interstates 90 and 29 had to be closed because of the snow accumulation on the roadway and poor visibility. One of these interstate closings led Davison and Codington counties to initiate their sheltering plans for travelers who could not find rooms at local motels. The storm also caused numerous cancellations and delays in school openings because of travel conditions or the lack of power. Interstate traffic was restored by early October 24. Twenty-eight counties were included in the disaster declaration: Aurora, Beadle, Bon Homme, Brookings, Brule, Buffalo, Charles Mix, Clark, Codington, Davison, Day, Deuel, Douglas, Grant, Gregory, Hamlin, Hanson, Hutchinson, Jerauld, Kingsbury, Lake, McCook, Marshall, Miner, Roberts, Sanborn, Spink, and Tripp Counties.
January–February 1995	**Severe Winter Storms (FEMA-1045-DR)** Damage to electric power lines in 21 counties was caused by an unusually foggy January weather. Continuous fog in many areas resulted in a heavy crust of ice forming on many of the power lines in central South Dakota. The fog-crust was reported to be three to five inches in diameter. The addition of high winds caused power poles to snap. Deep drifts of snow made it difficult for power company linemen to gain access to the damaged power lines, and in many areas, county snow removal equipment was required to provide access. According to reports, 13,435 households were without power for varying periods of time. The maximum time without power was 12 days. Early damage was estimated at more than $3.2 million. More than 1,700 power poles had to be replaced.
November–December 1983	Weeks of subzero temperatures preceded the actual blizzard and set the stage for the deadly combination of cold, blizzard conditions, and loss of electrical power. A series of winter storms struck South Dakota in late November and throughout December. The impact was felt statewide, but it was particularly heavy on the Rosebud and Pine Ridge reservations. Cheyenne River, Lower Brule, and Crow Creek reservations were also affected, but to a lesser degree. Many of the Rosebud and Pine Ridge communities had propane fueled/heated homes. At the height of the storms, reservation roads were drifted closed and became impassible. A fuel shortage occurred when the weeks of subzero temperatures drained propane tanks faster than normal. Tribal governments opened community shelters for those who

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	could make it to the shelters. As conditions worsened, fuel contractors could not start their delivery vehicles and roads were increasingly impassible. County and tribal government snowplows were overwhelmed by the enormity of the task. One death resulted from these storms.
October 9, 1981	The entire Black Hills area was virtually paralyzed by three to six feet of heavy snow and 40 to 70 mph winds. Roads were totally blocked, trees and power lines broken, and some homes sustained heavy damage. Not only were the northern hills residents isolated, but some were also without water and power for at least three days, causing food spoilage.
March 29, 1981	A winter storm front created a tornado near Martin, which destroyed a mobile home and injured one occupant. By 3:00 a.m. on March 30, the storm was generating 50 to 80 mph winds and dumping up to 10 inches of heavy, wet snow in the northwest. Power lines and at least 1,500 poles in the northwest were snapped after being coated with one to six inches of ice. Strong winds also snapped power lines and poles in south central South Dakota. These winds overturned trucks and cars along Interstate 29. The winds also overturned a railroad tank car, spilling phosphoric acid. This accident forced the evacuation of part of Garretson.
January 1981	A series of storms blocked the majority of roads in eastern South Dakota, over-turned vehicles, and stranded hundreds of motorists. The severity of these storms caused four deaths in vehicles stalled in the deep snow.
1977	February, March, and November were especially active months for winter storms. Many rural roads were blocked with snow drifts six to eight feet high. Interstate 90 was often blocked and up to 100 cars were stranded. Six people died as a result of these storms. In addition to power outages reported in various part of the state, the March storm dropped over an inch of rain in the eastern part of the state and generated walnut size hail in Grant County. In November, a winter storm toppled a 1,400 foot television tower and derailed six freight cars.
January 1975	Of the two blizzards in 1975, the one on January 11 and 12 was the worst. High winds exceeding 60 mph, subzero temperatures, and heavy snow combined to produce killer conditions. Several people died and thousands of head of livestock perished in eastern South Dakota.
March 1969	Heavy snowfall and high winds knocked out power in the Aberdeen area. Rural residents were hard hit as blocked roads prevented early power line repair. The Belle Fourche area also sustained loss of power and phone service as hundreds of poles were knocked down.
March 1966	This storm moved into eastern South Dakota and remained stationary for 12 hours. Winds of 60 to 70 mph were common. Gettysburg had gusts up to 100 mph. The driving wet snow clung to the mouths of livestock and they suffocated. Cattle and sheep loss approached 100,000 animals with a value of nearly $20 million. Many towns suffered physical damage from the storm. A total of 380 people in Pierre had to be evacuated as the result of a power failure. Many towns lost phone service, and some communities had windows shattered by high winds, allowing snow to drift into buildings. A 121-car train was completely stopped by snow drifts. This storm killed 10 people.
December 1965	An ice storm destroyed an estimated 3,500 telephone poles in the Aberdeen area. Damage was nearly $650,000. Total damage to light and power systems approached $1 million. At the time, this was the worst ice storm experienced in 40 years.
January 1952	The temperature dropped from 40°F to -8°F in a short period of time. The wet,

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	driving snow clung to everything. Cattle were blinded and suffocated as snow covered their mouths and noses. Young country school children lost their way home and died of hypothermia. A few ranchers died when they tried to gather their livestock. Snow piled up to a point that people could walk along tops of power lines. In some isolated areas, people were snowed in for four months off and on throughout the winter. Planes were used to deliver mail, groceries, fuel, and feed for livestock. Snow track vehicles were used to transport doctors to isolated farm areas.
January 1949	A blizzard affected the entire state. Blizzard conditions existed for weeks rather than days. The general weather conditions were low temperatures (-2°F to -8°F), heavy snows (24 inches for the month), and winds from 40 to 73 mph. Towns and rural areas were completely isolated as the snow blocked up everything. Roads, railroad tracks, and buildings were buried under tons of snow. People were lost in the storm and many cattle were frozen. Airplanes were used to deliver food, fuel, and medicine to stranded people. Snow was very deep in western South Dakota. Pictures of the area showed drifts 35 feet high and several thousand feet long.
1943	A blizzard killed a large number of cattle.
1927	A blizzard killed a large number of cattle.
May 1905	A blizzard hit western South Dakota counties in May. Cattle wandering around in the blizzard walked off the bluffs in the Badlands area and fell to their death. Estimated cattle loss exceeded 16,000.
January 12, 1888	A blizzard was preceded by 10 days of cold, snowy weather, 8 to 10 inches of new snow, and a low temperature of -28°F. The weather warmed on January 11 and 12; it was foggy and about 32°F. The temperature dropped on the afternoon of January 12 to -20°F in five minutes. The wind blew so strongly that it knocked people off their feet. Many children, sent home from school, did not make it home. The blizzard was so withering that people lost their sense of direction and wandered about until they died of hypothermia (exposure). Thousands of head of livestock and wild animals perished. Many buildings were covered with snow or destroyed, and all transportation stopped. Although the storm lasted less than one day, an estimated 400 people died throughout the Dakotas, 174 of which were in South Dakota.

Probability

According to the National Climatic Data Center Storm Events database, there were 1,462 winter storms (snow and ice events) in South Dakota between January 1993 and March 2016, and 295 extreme cold events from January 1994 to October 2012. This suggests that South Dakota experiences 63 winter storms and 12.8 extreme cold events each year. 12 deaths and 127 injuries were attributed to these events. This suggests that South Dakota can expect approximately 1 death every other year and 6 injuries each year. Based on this information, the probability that at least one winter storm will occur in South Dakota in any given year is 100 percent.

Climate Change Considerations

EPA research indicates that the amount of winter precipitation and the number of days with heavy snowfall are projected to increase in northern states. A warming climate may also result in warmer

winters, the benefits of which may include lower winter heating demand, less cold stress on humans and animals, and a longer growing season. However these benefits are expected to be offset by the negative consequences of warmer summer temperatures (see discussion under drought profile) according to the National Climate Assessment. Some pests and invasive weeds will be able to survive the warmer winters (see related discussion in Agricultural Pests and Diseases section). Winter crops that leave dormancy earlier are susceptible to spring freezes.

Wildfire

Description

Wildfires are uncontrolled conflagrations that spread freely through the environment. Wildfires near populated areas pose threats, not only to natural resources, but also to human life and personal property. Natural causes, such as lightning, or human acts may ignite wildfires. Lightning remains a fixed element of the ecosystem, and human-caused fire risks continue to increase as more and more people move to and recreate in fire-prone wildland areas.

South Dakota has a history of damaging wildfires. The state's susceptibility to wildfire was recognized nationally in 1897 when, prompted by a series of large forest fires in 1893, President Grover Cleveland established the Black Hills Forest Reserve to protect the forests from fires (as well as wasteful lumbering practices).

Prior to 2010, years of drought along with extremely low percentages of normal snowpack in the Black Hills created the potential for catastrophic wildfires in South Dakota. 2015 was a dry year, thus wildfire risk returned. Compounding this situation is the impact of the mountain pine beetle on pine trees in South Dakota. The most common host is the ponderosa pine. This tree occurs on more than 1 million acres of forestland in South Dakota. When the beetle population is very low, only stressed or weakened trees, such as those struck by lightning, are colonized. However, approximately every ten years the beetle population increases and the beetles begin colonizing healthy as well as stressed trees. The South Dakota Department of Agriculture (SDDA) reported in 2012 that the mountain pine beetle population had reached epidemic proportions. SDDA published a Black Hills Regional Mountain Pine Beetle Strategy (2012) which proposed mitigation strategies for reducing the population to endemic levels over the course of several years. Between mountain pine beetles and dry conditions, there is great concern for wildfires in the wildland-urban interface and also for agricultural and rural wildfires. Fires involving grass, prairie, or timber can cause mass destruction of property and vegetation.

South Dakota's semi-arid climate, highly flammable native vegetation, rugged terrain, and populated wildland-urban interface up its wildfire make hazard.

Topography—The Black Hills are an outcropping of the Rocky Mountains, lying in an ellipse 100 miles long and 50 miles wide along the state's western edge. In the Black Hills, terrain varies from broad, open valleys; rolling topography; mountainous terrain up to 7,242 feet in elevation; and steep, narrow canyons.

Fuels—Fuels are generally conducive to high rates of spread, represented by National Fire Danger Rating System fuel models "G", "L," "K," and "C." Grass predominates in the broad valley bottoms. Ponderosa

Pine grows on all aspects, and extensive pure forests of Ponderosa grow in the Black Hills. Mixed grass and timber stands occur in many areas depending on aspect. Fuel loading is lightest in the southern Black Hills and heaviest in the northern Black Hills.

Weather—During the summer months, temperatures are often in the 90s and low 100s with relative humidity in the teens. The average annual precipitation is approximately 17.5 inches. Some of this precipitation comes in association with thunderstorms that bring lightning during the fire season.

Lightning fires burn more acreage than human-caused fires, in part, because 1) multiple lightning fire ignitions often occur at the same time; 2) lightning fires can occur throughout the protection area, while most human-caused fires occur in accessible areas; 3) people often detect and report human-caused fires quickly due to their proximity to inhabited areas; and 4) lightning producing thunderstorms typically occur during the hottest portion of the fire season, while many human-caused fires start during spring or fall.

Conditions—The Black Hills ecosystem is fire adapted, having evolved with fire and fire dependent plant species. The forests of the Black Hills are very different from pre-settlement times when frequent, low-intensity fires maintained a healthy forest structure. Ponderosa Pine is adapted to benefit from frequent, low-intensity fires started in summer by lightning. Historically, these fires killed smaller plants that competed with the pines for moisture and released nutrients from litter on the forest floor. These fires also prevented accumulation of fuels that feed severe fires, which can destroy the thick-bark defense of the trees.

Today, the forest contains many more trees per acre and much more undergrowth, needle litter and deadwood than it did historically. Under these circumstances, when wildfires occur under dry, warm, and windy conditions, they will frequently develop into uncontrollable crown fires that destroy the forest and any homes within it.

Mountain pine beetle attacks in Ponderosa Pine often coincide with abundant weak trees resulting from drought and overgrown conditions. These circumstances have been common throughout the Black Hills and have allowed a mountain pine beetle infestation to become epidemic. The Custer State Park area around Harney Peak, and the Norbeck Wildlife Preserve adjacent to Mount Rushmore has extremely high fuel loading due to Mountain Pine Beetle outbreaks.

Wildland-Urban Interface—Wildfires destroy hundreds of structures throughout the western United States every year. These fires can and will occur anywhere that humans and their development meet or intermix with wildland fuels. This wildland-urban interface fire problem exists in every state, including South Dakota, and worsens each year. People continue to develop residential properties in fire-prone environments, increasingly exposing themselves and their personal property to the risks of wildfire. Fire and resource management professionals know that wildland-urban interface development can draw the efforts of firefighters away from protecting the natural resources, whose stewardship they are charged with.

Location

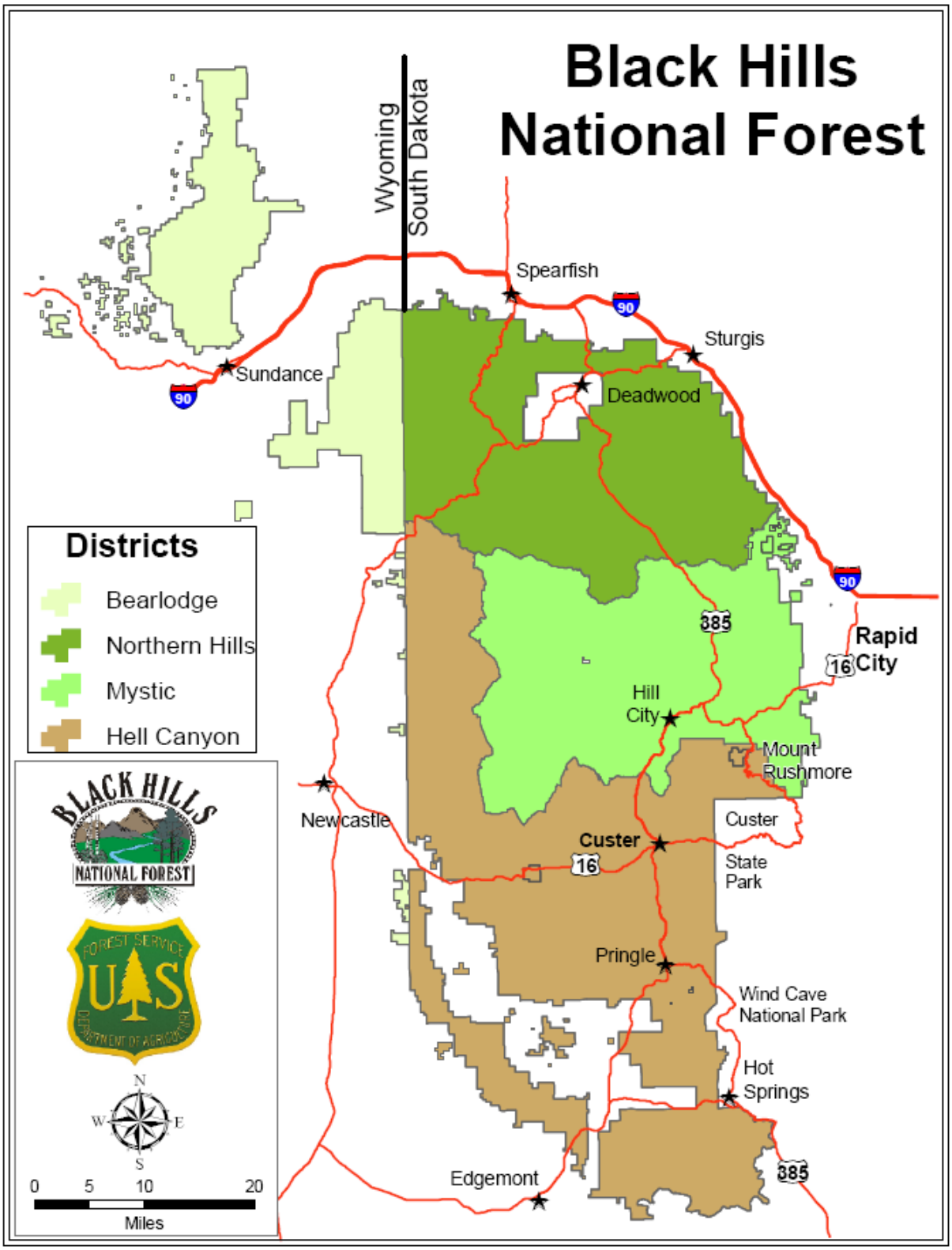
Early writings by explorers, trappers, and settlers often describe South Dakota as a sea of waving grass. The descriptions would not be valid today for the eastern half of the state. The more fertile and

climatically desirable prairie of the eastern portion is now used for crop production. But, the wild prairie still exists in the western part of the state. South Dakota's portion of the Great Plains now exists from the foothills of the Black Hills to the western boundary of the Missouri River. This amounts to nearly 35,000 square miles of land, which is used primarily for livestock grazing and some wheat cultivation. For most of the year, this area is at risk to wildfires because of the nature of the ground cover and the limited precipitation.

Although wildfires occur throughout the state, the grass and forestland areas west of the Missouri River represent the area most prone to large wildfires. This area remains vulnerable due to the large areas of continuous fuels and the extreme burning conditions that occur in the area. The area of the state known as the Black Hills has the highest potential for loss of lives and personal property from wildfire. After years of fire suppression, the landscape of the Black Hills has become a dense forest. High fuel loads, years of drought, and mountain pine beetle infestation have combined to make the area particularly susceptible to wildfire. Between 2000 and 2002, 10 percent of the Black Hills National Forest burned (see Past Events) (U.S. Forest Service, Spearfish, South Dakota, and the Northern Black Hills: Steps to Improve Community Preparedness for Wildfire).

The Black Hills National Forest encompasses 1,534,471 acres of land in South Dakota and Wyoming (see Figure 3-15). Over one million acres of the forest are exclusively in South Dakota (Custer, Fall River, Lawrence, Meade, and Pennington counties). Of the one million acres, about 80 percent is federally controlled. The remaining 20 percent is controlled by the state and private citizens.

Figure 3-15: Map of Black Hills National Forest with District Boundaries



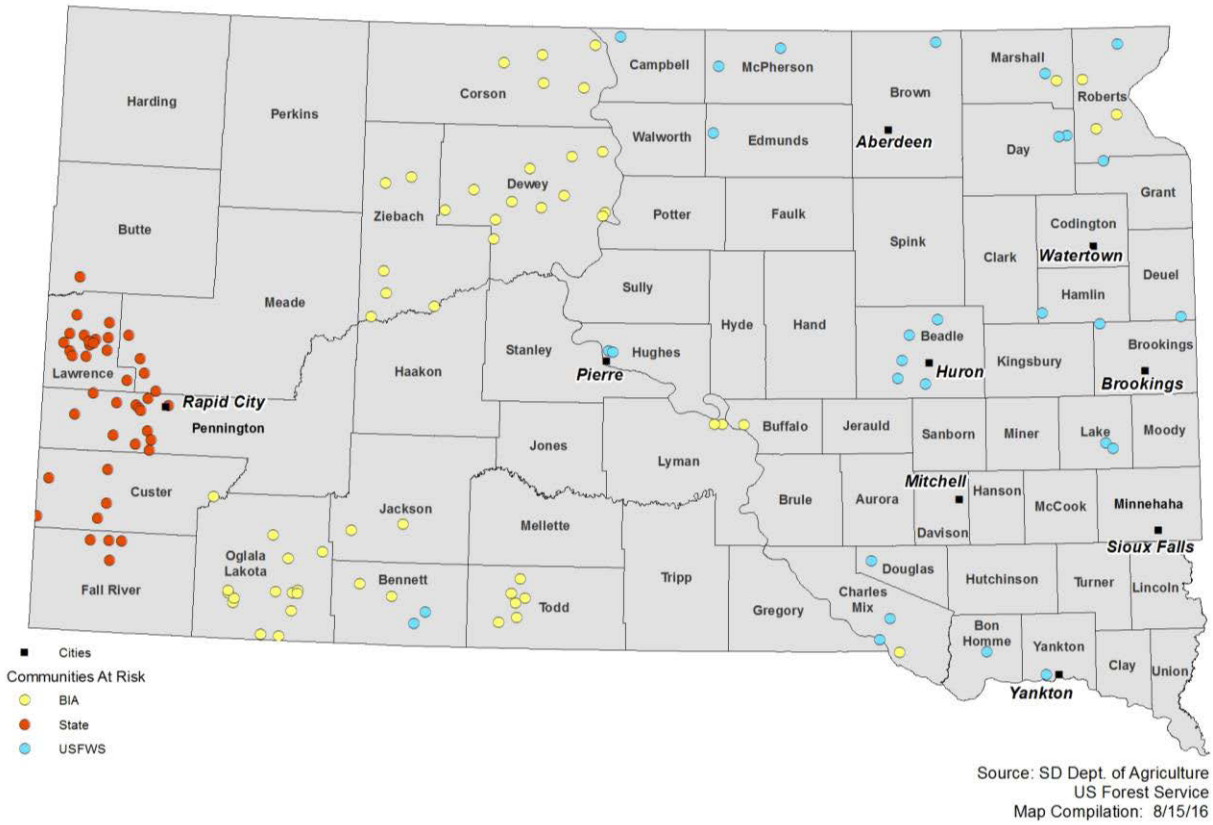
Source: U.S. Forest Service, http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5228288.pdf

The land ownership pattern in the Black Hills includes a mix of private, Black Hills National Forest, State of South Dakota, Bureau of Land Management, and National Park Service lands. A "checkerboard" ownership pattern in the Black Hills National Forest produces a condition where private, residential structures are scattered throughout much of the National Forest. The U.S. Forest Service has reduced, through land exchanges, the number of individual property inholdings and the land area they cover within the Black Hills National Forest. However, the number of occupied developments on the remaining inholdings increases constantly. This rural residential growth continually and dramatically increases private property exposure within U.S. Forest Service's fire jurisdiction.

The state primarily maintains fire protection responsibility on private and state lands, but protects a relatively large amount of Federal land as well. The State of South Dakota (WFS) is the protecting agency (under contract) for all BLM lands in SD, approximately 250,000 acres. In addition we provide mutual aid assistance to our federal wildland firefighting agencies throughout the state. Since a large portion of the state's fire protection area is private land, single-family dwellings exist throughout the state's protection area. However, there are existing pockets with no dwellings due to the roughness of the terrain in some areas.

The greatest concentration of structures is located in and around the towns and cities in the Black Hills, including subdivisions within a few miles of the town and city limits. Rapid City and bedroom communities within a five-mile radius of the city represent the greatest concentration of structures located in the forested areas of the Black Hills. The population of new residents is growing, especially in Custer, Pennington, and Meade Counties, and there are far more individual property owners to deal with than in the past. Figure 3-15 displays growing communities at risk to wildfires.

Figure 3-16 South Dakota Communities at Risk to Wildfire



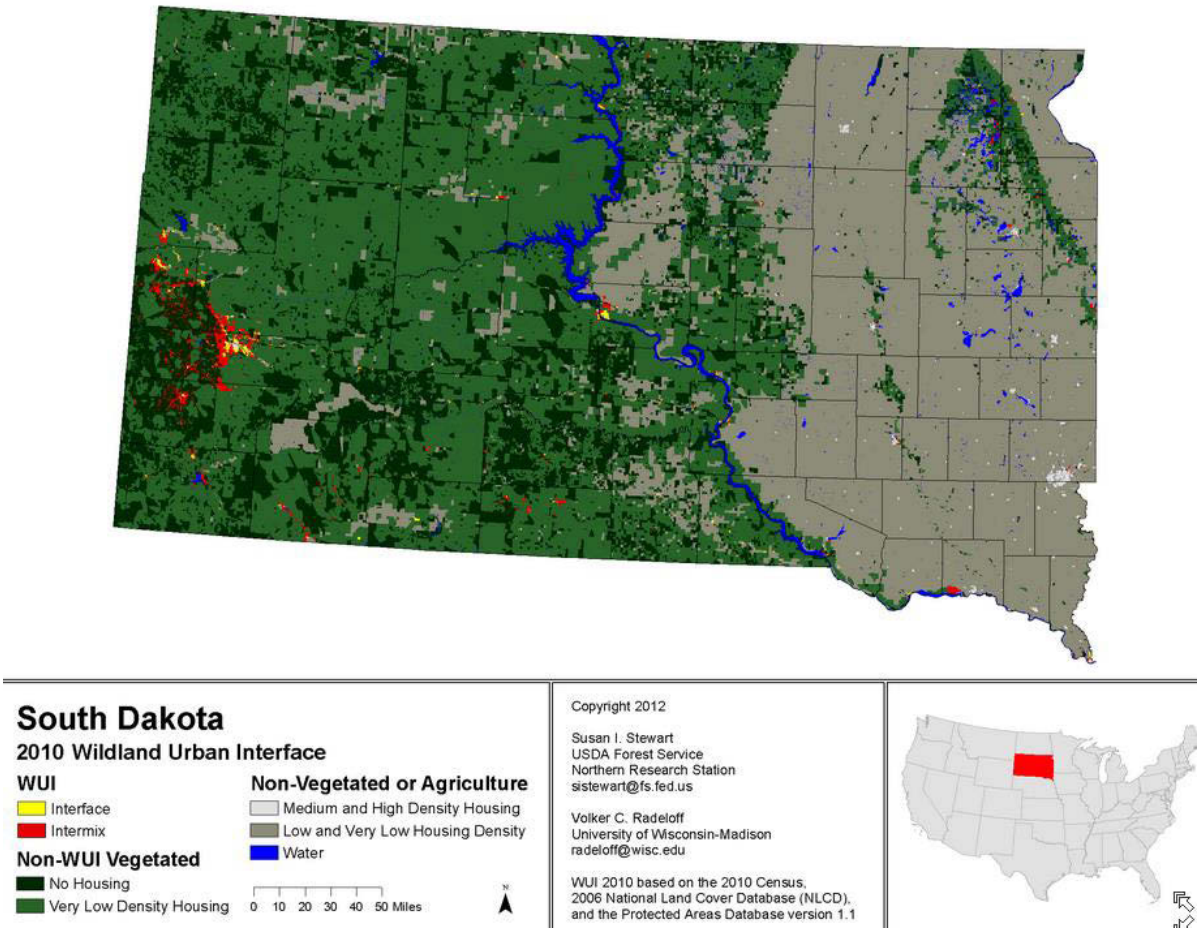
Many new residents are unfamiliar with the realities and responsibilities of living in a fire dependent ecosystem such as the Black Hills, are unaware of the natural role of fire, the concept of defensible space, and the capabilities of local government services. Many homeowners seem to value aesthetics more than safety and resist the concept of defensible space, believing that they will spoil the environment for which they came.

In addition to the Black Hills National Forest, there are fire-prone smaller forested areas on the Custer National Forest in Harding County, and BIA Trust and tribal lands on the Pine Ridge Reservation of Oglala Lakota County (unorganized), and the Rosebud reservation of Todd County (also unorganized). These three counties are in western South Dakota.

South Dakota codified law (SDCL 41-20-5) was amended in 2008 and now contains language that expands the use of the Fire Suppression Special Revenue Fund to include rangeland fires outside the Black Hills Forest Fire Protection District. The Governor has to declare an emergency for the area affected by the rangeland fire and the State Wildland Fire Suppression Division must assist with the fire suppression and extinguishment. Figure 3-17 illustrates South Dakota's wildland-urban interface using 2010 U.S. Census data. Wildland-urban interface, as illustrated in this figure from the SILVIS Lab at the University of Wisconsin–Madison, is composed of both interface and intermix communities. In both interface and intermix communities, housing must meet or exceed a minimum density of one structure per 40 acres. Intermix communities are places where housing and vegetation intermingle. In intermix, wildland vegetation is continuous, more than 50 percent vegetation, in areas with more than 1 house per

40 acres. Interface communities are areas with housing in the vicinity of contiguous vegetation. Interface areas have more than 1 house per 40 acres, have less than 50 percent vegetation, and are within 1.5 miles of an area (made up of one or more contiguous Census blocks) over 1,325 acres that is more than 75 percent vegetated. The minimum size limit ensures that areas surrounding small urban parks are not classified as interface WUI.

Figure 3-17: South Dakota's Wildland-Urban Interface



Source: SILVIS Lab, Forest Ecology and Management, University of Wisconsin–Madison, 2012

Past Events

The South Dakota Department of Agriculture's Division of Wildland Fire Suppression database indicates that lightning represents the single largest ignition source in its jurisdiction, causing 35 percent of fires and burning 41 percent of the acreage lost between 1996 and 2000. While debris burning caused slightly more fires, these fires burned only about one third of the acreage lost to lightning-caused fires. Figure 3-15 contains information about wildfires in the Black Hills between 1977 and 2000. Most of the fire occurrence and corresponding acres burned in the Black Hills occur in Custer and Fall River Counties.

South Dakota received two Fire Management Assistance Declarations in 2012. The Myrtle Fire (FEMA-2996-FM) began on July 19th, 2012 in Custer County due to human causes. The fire burned 10,080 acres and was 100% contained by July 24th, 2012. The Wellnitz Fire (FEMA-5010-FM) began on August 29th due to lightning. The fire burned 77,159 acres across Oglala Lakota County (previously Shannon

County), South Dakota and into Nebraska. Burned acreage in South Dakota alone was estimated at 28,478. The fire was 100% contained by September 7, 2012. NCDC recorded three wildfire events in South Dakota since 2010. These events are summarized in Table 3-18.

Additional data on wildfire occurrences was obtained from the Federal Wildland Fire Occurrence website (http://wildfire.cr.usgs.gov/firehistory/data.html). The Federal Wildland Fire Occurrence data had records for 26,808 fires between 1980 and 2015 of varying sizes between 0 and 84,782 acres. These fires burned an estimated total of 1,340,965 acres. The largest of these was the Jasper Fire complex in August 2000, which is profiled in Table 3-18. 88% of these fires between 0.1 and 84,782 acres were human-caused, 10% resulted from natural causes, and the causes of the remaining 2% were unknown. 191 fires between 1980 and 2015 burned 1,000 acres or more. Collectively these 191 fires burned a total of 1,058,056 acres. 121 (63%) of these fires occurred due to human causes, and the remaining 70 (37%) occurred due to natural causes. The location and cause distribution of the 191 events are depicted in Figure 3-18 and Figure 3-19, respectively.

Figure 3-18 South Dakota Fire Occurrences 1,000 Acres or More: 1980-2016

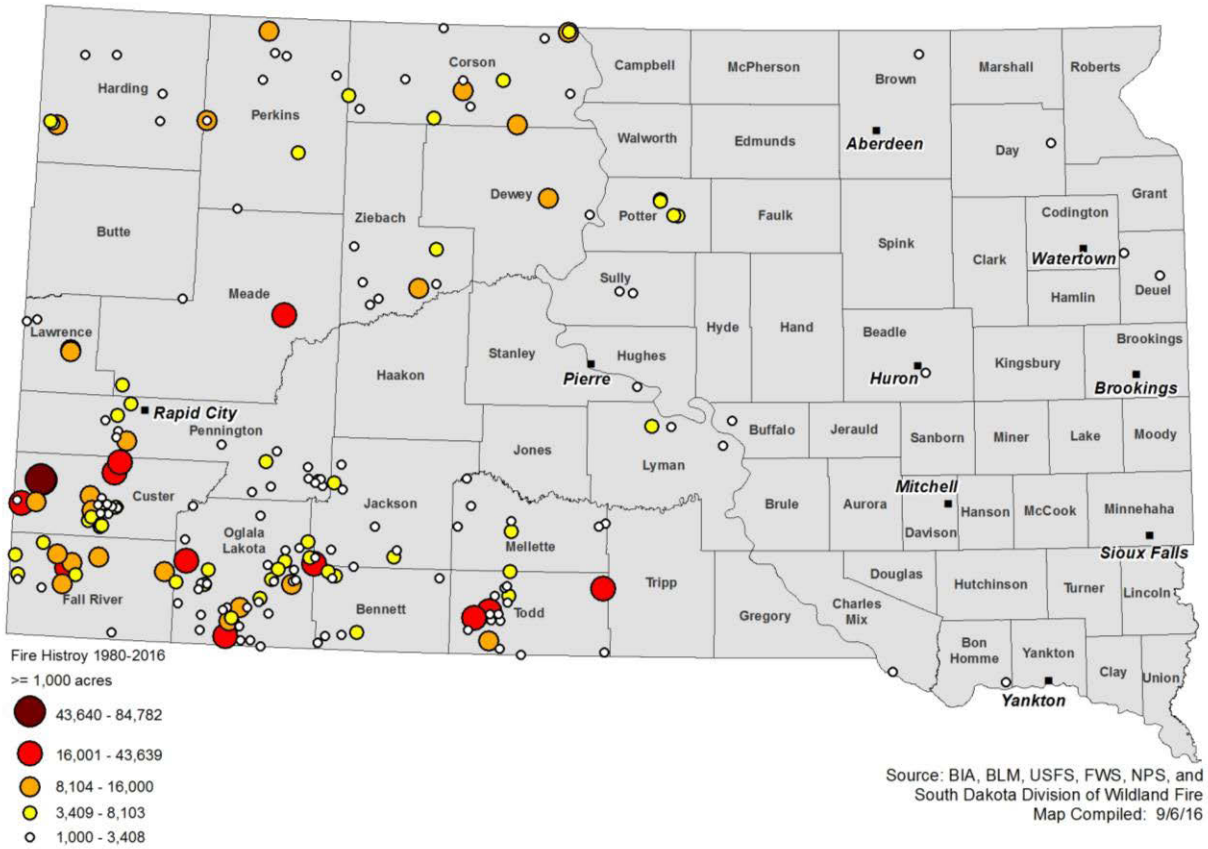


Figure 3-19 South Dakota Fire Occurrence Causes (1000 Acres or more): 1980-2016

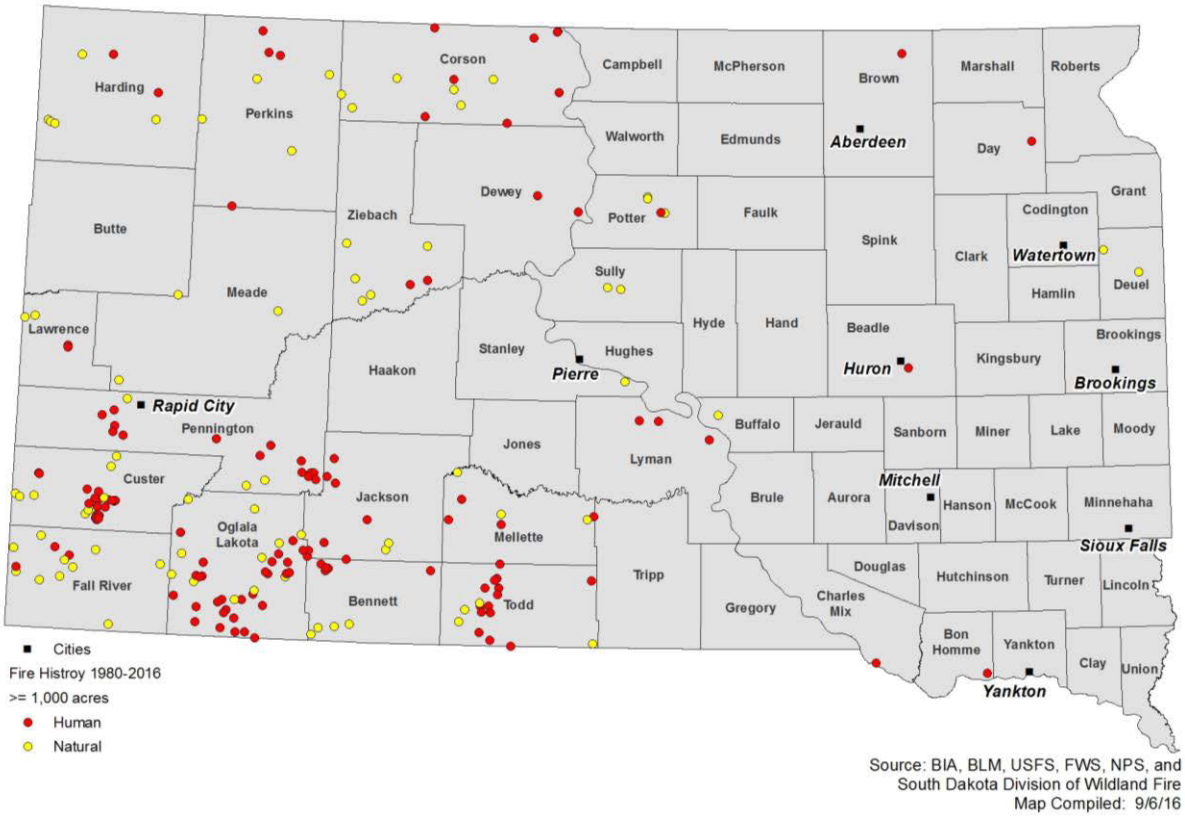


Table 3-18: South Dakota Wildfire Events

Date	Comments
2015	**Sheep Draw Fire** The Sheep Draw Fire in northwest South Dakota was estimated at 13,949 acres. One non-commercial structure was burned. No injuries reported.
2013	**Pautre Fire** Planned to be a prescribed fire up to 210 acres on the Dakota Prairie National Grasslands, strong winds pushed the fire across a mowed fire line into tall grass and ultimately burned 10,679 acres.
2012	**Crookston Fire** Driven by strong winds, the blaze started northeast of Kilgore and burned its way down to Crookston, Nebraska. The smoke was so thick firefighters closed the highway west of Valentine, Nebraska.
August 29, 2012	**Wellnitz Fire (FEMA-5010-FM)** The Wellnitz Fire began on August 29th due to lightning. The fire burned 77,159 acres across Oglala Lakota County (previously Shannon County), South Dakota and into Nebraska. Burned acreage in South Dakota alone was estimated at 28,478. The fire was 100% contained by September 7, 2012.
August 16, 2012	A wildfire burned grassland in and near the Karl E. Mundt National Wildfire Refuge in southeastern Gregory County South Dakota on August 16th. No structures were burned. The fire burned 146 acres, including 112 acres on the refuge and 34 acres of private land.

Date	Comments
July 19, 2012	**Myrtle Fire (FEMA-2996-FM)** South Dakota received two Fire Management Assistance Declarations in 2012. The Myrtle Fire began on July 19th, 2012 in Custer County due to human causes. The fire burned 10,080 acres and was 100% contained by July 24th, 2012.
January 9, 2012	Unseasonably warm and dry weather, along with dry and dormant vegetation, provided a setting in which several fires that were started to burn trash and vegetation went out of control in Moody County. The largest was several miles northeast of Flandreau, where the burning of a tree pile spread to grassland. This fire burned about 120 acres, reaching to the eastern border of the county and state. Another fire just northwest of Flandreau, started to burn garbage, burned 4 acres of grassland. No indications of damage amounts were received, but no structures were reported to have burned.
October 4, 2011	Several wildfires broke out in Gregory and Charles Mix counties during the four day period. Warm and dry weather, strong winds, and dry vegetation due to extended dry weather preceding this time contributed to the fires starting and spreading. The fires affected grassland and cropland, including baled hay.
2011	740 fires burned 38,684.62 acres
2010	609 fires burned 13,448.181 acres
August 27, 2010	**Flynn Creek Fire-**Human caused fire that burned 65 acres of US Forest Service Southeast of Custer, SD
2009	495 fires burned 11,372.499 acres
July 24, 2009	**Duck Creek Fire-**Railroad caused fire that burned 342.95 acres on US Forest Service Southwest of Hot Springs, SD
2008	476 fires burned 7,088.953 acres
May 18, 2008	**Freeland Well Fire-**Human caused fire that burned 168 acres on US Forest Service South of Custer, SD
2007	808 fires burned 160,851.23 acres
July 2007	**Boxelder Fire (FEMA-2716-FSA)** At the time of the state's request, the fire had burned approximately 700 acres and had resulted in the evacuation of 100 residents from the town of Nemo in Lawrence County.
July 2007	**Alabaugh Fire (FEMA-2710-FSA)** This fire near Hot Springs in Fall River County was started by lightning on July 7 and was contained on July 12. It burned 10,324 acres. The fire killed one man and destroyed 33 homes. It also forced the evacuation of about 600 residents in about 300 homes. Fire suppression costs were estimated at $2.7 million. A state official said the blaze was the most intense wildfire ever recorded in the Black Hills. Sources: InciWeb, Rapid City Journal, National Public Radio
2006	1,388 fires burned 371,226.31 acres Source: Steve Hasenohrl, South Dakota Chief Fire Management Officer
July 2006	**East Ridge Fire (FEMA-2658-FSA)** 3,204 acres burned, $1,973,107 total outlay
2005	781 fires burned 45,323.641 acres
July 2005	**Skyline #2 Fire (FEMA-2569-FSA)** 42 acres burned, total outlay: $18,975 (FEMA share: $14,231)
July 2005	**Ricco Fire (FEMA-2565-FSA)** 3,939 acres burned in Meade County, started by lightning, total outlay: $573,581 (FEMA share: $428,064)

Date	Comments
April 2005	**Camp Five Fire (FEMA-2557-FSA)** 775 acres burned. Request for assistance withdrawn because event did not meet fire cost thresholds.
2004	437 fires burned 15,517.87 acres
2003	710 fires burned 111,999.37 acres
November 2003	**Mill Road Fire (FEMA-2513-FSA)** Total outlay: $62,852 (FEMA share: $45,685)
2002	846 fires burned 179,287.9 acres
August 2002	**Battle Creek Fire (FEMA-2458-FSA)** On August 16, 2002, the Battle Creek Fire ignited on private land near Keystone. High temperatures, low relative humidity, and strong winds created conditions that led to intense fire behavior with long-range spotting. The fire burned actively for four days and burned 12,450 acres (9,120 acres of national forest system lands, 3,330 acres of private lands) before it was fully contained on August 25. Over 600 structures and the town of Keystone were threatened, but thanks to firefighters, losses were limited to three residences near Hayward. Source: U.S. Forest Service, Battle Creek Fire Rapid Assessment (www.fs.fed.us/r2/blackhills/fire/history/battlecreek/index.shtml) Total outlay: $1.8 million
June–July 2002	**Grizzly Gulch Fire (FEMA-2434-FSA)** This fire near Deadwood and Lead burned 10,801 acres and destroyed 7 homes and 20 other structures. Source: Jerome Harvey, "Historic Wildfire in the Black Hills" (www.nfpa.org/assets/files/PDF/blackhills.pdf)
2001	611 fires burned 124,401.74 acres
July–August 2001	**Elk Mountain #2 Fire (FEMA-2369-FSA) This** fire burned mostly in Wyoming, but was complexed with the Roger's Shack fire which burned 11,896 acres in South Dakota in western Custer County. Two single family residential homes were lost. Total outlay: $293,000
August–September 2000	**Flagpole Fire Complex (FEMA-2319-FSA) and Jasper Fire (FEMA-2324-FSA)** The Flagpole fire complex started on August 11, 2000, in Fall River County in southwestern South Dakota. The wildfire was actually three different starts, the Flagpole Mountain, Green Canyon, and Chilson II fires in the southern hills area. The fires were attributed to lightning. The Flagpole Mountain fire burned in ponderosa pine; the Green Canyon fire burned in grass, scrub, and juniper. The terrain was extremely rocky and steep, making access and fire-fighting difficult. Pushed by shifting winds, the Flagpole fire immediately threatened structures, including two homes, and destroyed one outbuilding. The Flagpole and Chilson II fires burned more than 6,000 acres by the evening of August 12. The Flagpole fire threatened 30 homes on the north, south, and east sides of the fire and prompted officials to call for voluntary evacuations in the Shep's Canyon area, where there was only one access road. One residence was lost on the north side of the fire. The fires eventually burned 7,386 acres. The Jasper Fire was located in Custer County in the Southwest Black Hills. It was the largest fire to occur in the Black Hills in at least a century. The fire started at about 2:30 p.m. on August 24, 2000, and was contained on September 8, 2000. The cause of the fire was arson. The weather was very hot and dry, vegetation moisture was at record low levels, and atmospheric conditions were very unstable. The conditions caused extreme fire

Date	Comments
	behavior and the fire spread rapidly, doubling in size every hour on the day it started. Almost immediately after ignition, the fire spread into the tops of the trees and blowing embers began causing spot fires ahead of the main fire. The fire created its own weather pattern as it burned. Lightning from the storm created by the fire was a big concern. The fire completely blackened some areas, leaving scorched, dead trees and ash-covered ground in its wake. Other areas experienced only a light ground burn. Large areas within the fire perimeter remained green, either lightly burned or completely undamaged. Firefighting efforts continued for a month, and firefighters declared the fire controlled on the evening of September 25, 2000. The Jasper fire burned 83,500 acres and was the largest fire in Black Hills history. It destroyed one summer cabin and three outbuildings, burned acreage at the Jewel Cave National Monument, and threatened more than 100 other structures and the communities of Custer and Hill City. Fire losses included approximately 244 million board feet of timber, 150 miles of range fence, 65 livestock water tanks, 20 miles of range water lines, 17 wildlife water developments, 59 wooden power line structures, and 2,738 feet of above ground telephone line. Total outlay for both fires: $4.25 million
2000	1,348 fires burned 354,357.13 acres
1999	879 fires burned 161,972.42 acres
1998	208 fires burned 6,843.96 acres
1997	69 fires burned 1,353.65 acres.
March 28, 1997	**Burdock Fire**-burned 350 acres on Private
1996	69 fires burned 3,484.57 acres
February 10, 1996	**East Gate Fire**- Powerline fire that burned 996 acres on Private
1995	56 fires burned 1,588.97 acres
September 5, 1995	**Indian Canyon Fire**- Lightning caused fire on Private burned 1,504 acres
1994	201 fires burned 2,663 acres [includes Stagebarn Canyon].
August 15, 1994	**Stagebarn Canyon Fire (FEMA-2109-FSA)** Stagebarn Canyon near Indian Hills subdivision northwest of Rapid City. Fire started by lightning. 112 acres burned; cost in excess of $159,000.
1993	44 fires burned 678 acres.
1992	958 fires burned 20,367 acres.
1991	815 fires burned 43,782 acres.
September 1990	**Swedlund Fire (Cicero Peak fire) (FEMA-2076-FSA)** Burned 14,518 acres, approximately 5,000 acres in Custer State Park. Caused by logging equipment.
1990	860 fires burned 11,725 acres.
1989	911 fires burned 14,779 acres.
1988	1,171 fires burned 69,512 acres.
July 5, 1988	**Galena Fire** 16,788 acres burned in Custer State Park. Started by lightning and required the evacuation of the City of Keystone during the height of tourist season. (http://thune.senate.gov/public/index.cfm?FuseAction=PressReleases.Detail&PressRelease_id=427&Month=3&Year=2007) (WFS Agency Historical Archives)
Jul 25, 1988	**Westberry Trail Fire (FEMA-2068-FSA)**

Date	Comments
	Suspected arson fire and was located in a subdivision on the western edge of Rapid City. Burned 14 homes and 3,980 acres.
June 20, 1988	**The Short Pines Fire** in Harding County started by lightning burned over 5,274 acres of School and Public state land and one 105 acre fire started by a powerline in Rapid City on Skyline Drive destroyed one single family residence.
Jul 20, 1987	**Battle Mountain Fire (FEMA-2061-FSA)** Started by lightning in the game production area, two miles from Hot Springs. Burned 2,200 acres.
1987	1,638 fires burned 52,277 acres.
1986	478 fires burned 3,572 acres.
July 12, 1985	**Flint Hill Fire (FEMA-2057-FSA)** Lightning caused fire that burned 23,000 acres west of Edgemont.
July 12, 1985	**Seven Sisters Fire (FEMA-2056-FSA)** Lightning cause fire that burned 9,300 acres south of Hot Springs.
1985	1,229 fires burned 110,669 acres.
1984	651 fires burned 28,230 acres.
1983	950 fires burned 18,613 acres.
1982	403 fires burned 6,886 acres.
1981	1,556 fires burned 24,537 acres.
1980	1,349 fires burned 42,077 acres.
1979	485 fires burned 14,214 acres.
1978	479 fires burned 48,290 acres.
1977	535 fires burned 6,952 acres.
1976	582 fires burned 9,130 acres.
July 1975	**Custer State Park (FEMA-2017-FSA)**
1975	851 fires burned 30,671 acres
July 1974	**Argle & Booms Canyon (FEMA-2016-FSA)** Lightning caused fire that burned 4,356 acres north of Hot Springs.
1974	1,022 fires burned 38,864 acres.
1973	704 fires burned 36,252 acres.
1972	452 fires burned 13,638 acres.
1971	815 fires burned 20,890 acres.
1970	477 fires burned 6196 acres.
1969	211 fires burned 3254 acres.
November 21, 1962	Burned an area that stretched from Harrold to Highmore (20 miles long) and consumed 30,000 acres of hay and cropland. No loss of life.
August 30, 1960	Two simultaneous lightning strikes south of Hot Springs started the Green Canyon fire (6,389 acres) and the Wildcat fire (10, 454 acres).
September 8, 1959	This human-caused fire nearly destroyed the town of Deadwood. The fire burned 4,500 acres (1,971 federal, 2,560 private) around the town and did more than $1 million (1959 dollars) in damage. More than 60 structures (businesses, residences, utilities, etc.) were destroyed and damage to infrastructure was severe. Nearly 4,000 people were evacuated from the town in less than 30 minutes. Source: Jerome Harvey, "Historic Wildfire in the Black Hills" (www.nfpa.org/assets/files/PDF/blackhills.pdf)
August 23, 1949	Human-caused forest fire started by Nemo. Burned out to the hogback area by Tilford. Burned 6,630 acres and required both the SDNG and Rapid City Air Base

Date	Comments
	to provide over a 1000 personnel to the Black Hills NF to suppress the fire. (Source: Big Elk fire file, WFS agency historical archives)
September 5, 1947	Three human-caused fires burned into one conflagration that burned an estimated 320,000 acres in Hyde, Sully, Potter, Faulk and Hughes Counties in one day. Estimated $2,000,000 damage to improvements (1947 dollars). Considerable damage to range and farm land, (Source: WFS agency historical archives and *"75 Years of Sully County History*" published by the *Onida Watchman.*
July 10, 1939	**McVey Fire** by Hill City South Dakota. Cause is still unclear. Burned 21, 857 acres. Almost burned over the town of Hill City. One firefighter was killed by a lightning strike during mop-up. 45 miles of fireline was constructed by over 1775 men at the height of the blaze. (Source*: Sawmills of the Black Hills*, by M. Linde and WFS agency archives.
1931	Rochford Burn. Arson set forest fire. Burned approximately 20,900 acres in western Pennington County in the high elevation limestone country of the Black Hills National Forest, 12 structures were lost. (Source: WFS Agency historical archives)
1899	The Iron Creek fire burned for most of August south of Spearfish. By the time winter snows arrived, it had burned 38,400 acres of timber on the Black Hills National Forest and numerous mining claims.
March 1879	This fire burned for at least one week in an area from Brookings County to Union County. The path was over 100 miles long and 20 miles wide.
October 1871	During the week of the Great Chicago fire, a large wildland fire occurred along the Missouri River burning from Springfield to Yankton, burning many structures and farms.

Source: NCDC, Federal Wildland Fire Occurrence Database, South Dakota Department of Agriculture Division of Wildland Fire Suppression

Probability

As shown in the differences in fires reported in Table 3-18: South Dakota Wildfire Events, wildfire reporting in the State varies regionally. Using the data in Table 3-18 (excluding the outlier of the 1879 fire), there were 87 wildfire events in South Dakota between 1871 and 2016 (48 years). Given both sets of data, wildfires, including those of a significant size, have a 100% chance of occurrence somewhere in the state from early spring to late fall every year.

According to the Federal Wildland Fire Occurrence data, 163 significant fires (1,000 acres or more in size) occurred between 1980 and 2011. Based on this data there is a 100% chance that a large fire of 1,000 acres or more will occur in South Dakota in any given year. Smaller fires also have a 100% annual occurrence probability.

Climate Change Considerations

Wildfire conditions across South Dakota and the western United States in general are likely to worsen in the future due to climate change given that climate projections indicate continued increasing summer temperatures and milder temperatures overall, thus an extended fire season. The US Forest Service released a study titled "Wildland Fire and Climate Change" detailing the effect climate change will likely have on atmospheric patterns that affect fire weather. These changes could result in fire patterns that will in turn impact carbon cycling, forest structure, and species composition. The study explains that with a doubled CO2 environment, there is potential for an increase in lightning activity, a higher frequency of

surface pressure and associated circulation patterns conducive to surface drying, and fire-weather conditions in general. These findings suggest that these factors and higher summer temperatures will likely increase the annual window of high fire risk by 10-30%. Predictions past 2040 are largely speculative given the current rate of increase in fossil fuel emissions, but there will certainly be in increase in the potential for drought and the number of days in a year with flammable fuels. The above variables will extend fire seasons and area burned in ecoregions where fire extent is linked to fuel conditions. More intense wildfires can produce highly erodible soils that can lead to increased sediment loading in reservoirs and streams, damaging water infrastructure and degrading water quality. This can also result in increased flood and debris flow risk in affected watersheds for many years following a destructive fire.

Drought

Description

According to the National Weather Service, "Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people. It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry. Human factors, such as water demand and water management, can exacerbate the impact that drought has on a region." Four common types of drought are defined below.

- Meteorological drought is most often described in terms of dryness and the duration of the dry period. Other types of drought typically begin with a meteorological drought.
- Hydrological drought usually occurs as a result of precipitation shortfalls that negatively impact water supply.
- Agricultural drought links impacts on agriculture to meteorological or hydrological drought with a focus on precipitation shortages, soil water deficits, reduced water levels needed for irrigation, etc.
- Socioeconomic drought refers to the situation that occurs when physical water shortages begin to affect people.

South Dakota is vulnerable to the social, economic, and environmental impacts of drought. Specifically, drought in South Dakota means limited water availability for people, agriculture, and recreation. The demand for water for multiple uses also impacts water availability. Rural water systems designed largely to supply water for people are now also being used for cattle and to fight wildfires, taxing the limits of the systems. These problems are only expected to get worse in the years to come as populations grow.

Drought in South Dakota is often accompanied by periods of extreme heat. According to information provided by FEMA, extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks. Heat kills by taxing the human body beyond its abilities. In a normal year, about 175 Americans succumb to the demands of summer heat. According to the National Weather Service (NWS), among natural hazards, only the cold of winter—not lightning, hurricanes, tornadoes, floods, or earthquakes—takes a greater toll. In the 40-year period from 1936 through 1975, nearly 20,000 people were killed in the United States by the effects of heat and solar radiation. In the heat wave of 1980, more than 1,250 people died.

Heat disorders generally have to do with a reduction or collapse of the body's ability to shed heat by circulatory changes and sweating or a chemical (salt) imbalance caused by too much sweating. When heat gain exceeds the level the body can remove, or when the body cannot compensate for fluids and salt lost through perspiration, the temperature of the body's inner core begins to rise and heat-related illness may develop. Elderly persons, small children, those with chronic illnesses, those on certain medications or drugs, and persons with weight and alcohol problems are particularly susceptible to heat reactions, especially during heat waves in areas where moderate climate usually prevails. The chart below illustrates the relationship of temperature and humidity to heat disorders.

Figure 3-20 National Weather Service Heat Index

NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	118	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	126	130					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Streuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Source: National Weather Service

Note: Heat Index (HI) values were devised for shady, light wind conditions. Exposure to full sunshine can increase HI values by up to 15°F. Also, strong winds, particularly with very hot, dry air, can be extremely hazardous.

The NWS has in place a system to initiate alert procedures (advisories or warnings) when the Heat Index is expected to have a significant impact on public safety. The expected severity of the heat determines whether advisories or warnings are issued. A common guideline for the issuance of excessive heat alerts is when the maximum daytime high is expected to equal or exceed 105°F and a nighttime minimum high of 80°F or above is expected for two or more consecutive days.

Location

No portion of the State of South Dakota is immune from drought conditions. The effects of drought vary based on where in the State it occurs, when it happens, and how long the drought persists. For example, a drought in East River (defined as the eastern half of the State east of the Missouri River) can greatly affect agricultural crops. A long-term drought is not needed to affect agricultural yields. Droughts of just a few weeks during critical periods of plant development can have disastrous effects on agriculture production. Droughts that occur in the Black Hills during winter months may affects winter sports related tourism and recreation. Droughts that occur in in the western part of the state may increase the threat of wildfire in the wildland urban interface areas. In summary, drought is one of the few hazards with the potential to directly or indirectly impact the entire population of the state, be it from water restrictions, higher water and food prices, reduced air or water quality, or restricted access to recreational areas (McKee and Doesken, 1999).

Past Events

A comprehensive compendium of historical drought information for South Dakota is difficult to find. The following is a summary of information on major droughts that have affected South Dakota, much of it based on data compiled from the National Climatic Data Center (NCDC) and State HMP.

1889–1905 – This multi-year, statewide drought was most severe between 1894 - 1896 and 1898 - 1901.

1910-1914 – This drought was worse in the western half of the state but regional impacts varied. It was most severe in 1911.

The 1930's Drought – The Dust Bowl drought severely affected much of the United States during the 1930s. The drought came in three waves, 1934, 1936, and 1939-1940, but some regions of the High Plains experienced drought conditions for as many as eight consecutive years. The soil, depleted of moisture, was lifted by the wind into great clouds of dust and sand which were so thick they concealed the sun for several days at a time. They were referred to as "black blizzards." The period itself is known as the dust bowl. The "black blizzards" were caused by sustained drought conditions compounded by years of land management practices that left topsoil susceptible to the forces of the wind.

The agricultural and economic damage devastated residents of the Great Plains. The Dust Bowl drought worsened the already severe economic crises that many Great Plains farmers faced. In the early 1930s, many farmers were trying to recover from economic losses suffered during the Great Depression. To compensate for these losses, they began to increase their crop yields. High production drove prices down, forcing farmers to keep increasing their production to pay for both their equipment and their land. When the drought hit, farmers could no longer produce enough crops to pay off loans or even pay for essential needs. Even with federal emergency aid, many Great Plains farmers could not withstand the economic impacts of the drought. Many farmers were forced off of their land. One in ten farms changed possession at the peak of the drought. The agricultural and economic damage devastated residents of the Great Plains.

Many factors contributed to the severe impact of this drought and in its aftermath a better understanding of the interactions between the natural elements (e.g., climate, plants, and soil) and human-related elements (e.g., agricultural practices, economics, and social conditions) of the Great Plains developed. As

a result, farmers adopted new cultivation methods to help control soil erosion in dry land ecosystems; consequently, subsequent droughts in the region have not had the same impact.

The 1950s Drought – Fueled by post-war economic stability and technological advancement, the 1950s represented a time of growth and prosperity for some Americans. But while much of the country celebrated a resurgence of well-being, many residents of the Great Plains and southwestern United States were suffering. During the 1950s, the Great Plains and the southwestern U.S. withstood a five-year drought, and in three of these years, drought conditions stretched coast to coast. The 1950s drought was characterized by both decreased rainfall and excessively high temperatures. The first effects of the drought were felt in the southwestern U.S. in 1950 and by 1953 conditions had spread to Oklahoma, Kansas, and Nebraska. By 1954, the drought encompassed a ten-state area reaching from the mid-west to the Great Plains, and southward into New Mexico. The area from the Texas panhandle to central and eastern South Dakota, western Kansas, and central Nebraska experienced severe drought conditions. The drought maintained a stronghold in the Great Plains, reaching a peak in 1956. The drought subsided in most areas with the spring rains of 1957. A disaster of this magnitude can create severe social and economic repercussions, as was the case in the southern Great Plains region. The drought devastated the region's agriculture, with crop yields in some areas decreased as much as 50%. Excessive temperatures and minimal rainfall scorched grasslands typically used for grazing. With grass scarce, hay prices rose, forcing some ranchers to feed their cattle a mixture of prickly pear cactus and molasses. By the time the drought subsided in 1957, many counties across the region were declared federal drought disaster areas (NCDC, 2003).

The 1975-1976 Drought – This drought was short but severe, and similar to the 2012-2013 drought in agricultural impacts. This drought resulted in the State's only drought emergency declaration (FEMA-3015-EM in 1976) to date.

The 1980-1982 Drought – This was a statewide drought that was most severe in 1981 and rated as a 10-25 year event.

The 1988-1992 Drought – This drought contributed to large wildland fires in the Black Hills. Conditions became so severe that the state considered using cloud seeding, despite the bad press associated with cloud seeding in the aftermath of the 1972 Rapid City flood.

The 2002-2007 Drought – The State also experienced significant droughts in 2002-2007. South Dakota dealt with impacts such as switching some reservoir intakes to river intakes in 2002-2003 because the reservoir levels receded below the intake. Water recreation declined in 2006. The 2002-2007 drought also exacerbated wildland fire risk, leading to a particularly bad fire season during 2006. The impacts of this drought are discussed in greater detail by sector in Chapter 3 Vulnerability Assessment.

The 2012-2013 Drought – The 2012-2013 drought wasn't as lengthy as other droughts but did have significant agricultural impacts. Shutoff orders were issued to water rights holders in the spring of 2012. The 2012-2013 drought actually created some positive aspects by offsetting the impacts of the floods during 2010-2011. The impacts of this drought are discussed in greater detail by sector in Section 3 Vulnerability Assessment.

Winter-Spring 2015 Drought - South Dakota experienced its driest January-April of any year on record since the late 1800s. Dry conditions continued across much of the state until mid-May when unusually

copious rainfall continued into June and virtually eliminated drought conditions and caused flooding issues instead.

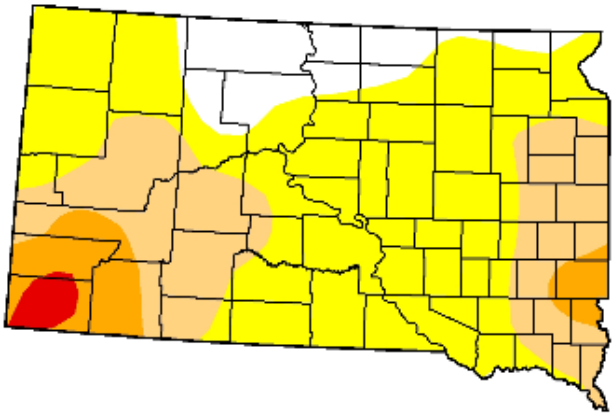
Figure 3-21: South Dakota Drought Status, July 24, 2007

U.S. Drought Monitor
South Dakota

July 24, 2007
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	11.3	88.7	33.8	9.0	1.5	0.0
Last Week (07/17/2007 map)	45.8	54.2	16.8	6.6	1.5	0.0
3 Months Ago (05/01/2007 map)	49.0	51.0	32.4	13.7	1.1	0.0
Start of Calendar Year (01/02/2007 map)	11.9	88.1	56.5	52.2	10.9	0.0
Start of Water Year (10/03/2006 map)	30.1	69.9	57.9	52.1	13.4	0.0
One Year Ago (07/25/2006 map)	0.0	100.0	100.0	81.0	54.6	18.9



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements

http://drought.unl.edu/dm

Released Thursday, July 26, 2007
Author: Richard Heim/Liz Love-Brotak, NOAA/NESDIS/NCDC

Source: University of Nebraska–Lincoln National Drought Mitigation Center
http://drought.unl.edu/dm/DM_state.htm?SD,HP

The Drought Monitor graphic in Figure 3-21 illustrates South Dakota's drought status as of July 24, 2007. Following Figure 3-19, a drought monitor graphic is shown for 2010, 2013, and 2016. Together the graphics show how intensity and coverage varies over time., and how drought conditions changed since 2007 from drought free in 2010 to intense drought in 2013.

Figure 3-22: South Dakota's Drought Status, July 27, 2010

U.S. Drought Monitor

South Dakota

July 27, 2010
Valid 7 a.m. EST

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	100.0	0.0	0.0	0.0	0.0	0.0
Last Week (07/20/2010 map)	100.0	0.0	0.0	0.0	0.0	0.0
3 Months Ago (05/04/2010 map)	100.0	0.0	0.0	0.0	0.0	0.0
Start of Calendar Year (01/05/2010 map)	100.0	0.0	0.0	0.0	0.0	0.0
Start of Water Year (10/06/2009 map)	97.0	3.0	0.0	0.0	0.0	0.0
One Year Ago (07/28/2009 map)	95.7	4.3	0.0	0.0	0.0	0.0

Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements

http://drought.unl.edu/dm

Released Thursday, July 29, 2010
Author: D. Miskus, CPC/NOAA

Source: University of Nebraska–Lincoln National Drought Mitigation Center
http://drought.unl.edu/dm/DM_state.htm?SD,HP

U.S. Drought Monitor archives indicate that most of 2011 was also a wet year for South Dakota. However, dry conditions returned that winter.

Figure 3-23: South Dakota's Drought Status, February 12, 2013

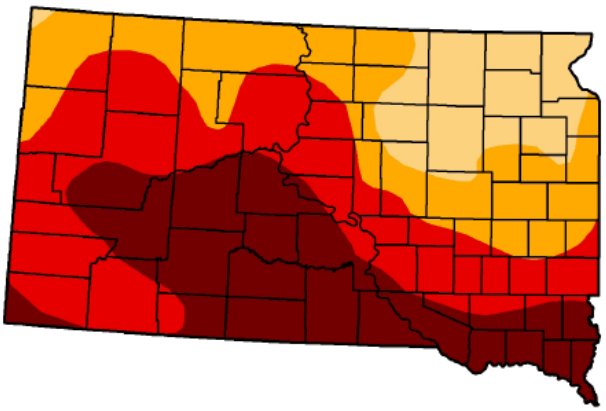
U.S. Drought Monitor

February 12, 2013
Valid 7 a.m. EST

South Dakota

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	86.77	63.21	29.58
Last Week (02/05/2013 map)	0.00	100.00	100.00	96.93	64.29	29.57
3 Months Ago (11/13/2012 map)	0.00	100.00	100.00	93.09	54.71	32.57
Start of Calendar Year (01/01/2013 map)	0.00	100.00	100.00	96.95	63.17	30.68
Start of Water Year (09/25/2012 map)	0.00	100.00	100.00	74.69	50.53	6.72
One Year Ago (02/07/2012 map)	30.59	69.41	20.25	1.65	0.00	0.00



Intensity:

- *D0 Abnormally Dry*
- *D1 Drought - Moderate*
- *D2 Drought - Severe*
- *D3 Drought - Extreme*
- *D4 Drought - Exceptional*

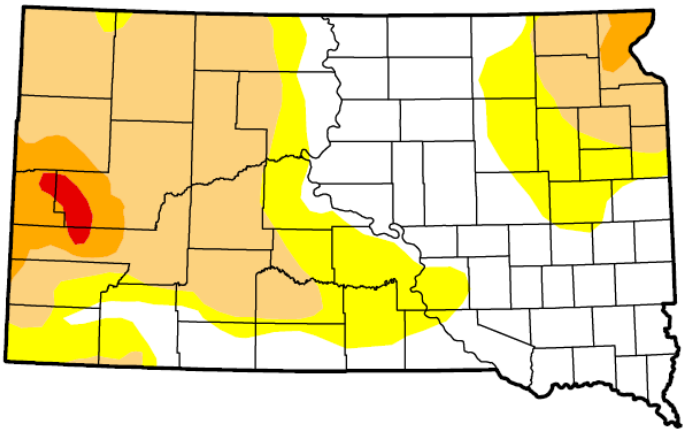
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu

Released Thursday, February 14, 2013
Michael Brewer, National Climatic Data Center, NOAA

Source: University of Nebraska–Lincoln National Drought Mitigation Center
http://drought.unl.edu/dm/DM_state.htm?SD,HP

Figure 3-24: South Dakota's Drought Status, July 5, 2016



U.S. Drought Monitor

South Dakota

July 5, 2016

(Released Thursday, Jul. 7, 2016)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	40.45	59.55	38.36	5.62	0.81	0.00
Last Week *6/28/2016*	38.52	61.48	38.91	5.81	0.81	0.00
3 Months Ago *4/5/2016*	74.27	25.73	0.00	0.00	0.00	0.00
Start of Calendar Year *12/29/2015*	89.43	10.57	0.00	0.00	0.00	0.00
Start of Water Year *9/29/2015*	94.77	5.23	0.00	0.00	0.00	0.00
One Year Ago *7/7/2015*	95.43	4.57	0.00	0.00	0.00	0.00

Intensity:

D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
David Miskus
NOAA/NWS/NCEP/CPC

http://droughtmonitor.unl.edu/

Historical drought information for South Dakota is difficult to find. An article in the *Proceedings of the South Dakota Academy of Science* suggests that South Dakota has seen droughts worse than the 1930's Dust Bowl. The article is based on a study of tree core data conducted to learn more about historical drought in South Dakota. The results of the study are illustrated in Table 3-19. According to the U.S. Drought Monitor, South Dakota remains in a moderate drought as of July 2016.

Table 3-19: Duration and Magnitude Estimates of 15 Dry and 15 Wet Spells in South Dakota

	Dry Periods			Wet Periods		
Rank	Years	No. Years	% of Max	Years	No. Years	% of Max
1	1531-1551*	21	100.0	1429-1448*	20	100.0
2	1325-1344*	20	90.8	1284-1297*	14	80.3
3	1859-1873	15	82.5	1559-1574*	16	66.0
4	1397-1411*	15	73.0	1609-1617	9	53.6
5	1710-1725	16	65.8	1762-1769	8	35.7
6	1780-1791	12	51.3	1882-1892	11	31.5
7	1933-1942	10	50.0	1683-1695	12	30.0
8	1753-1761	9	43.5	1792-1806	15	28.1
9	1660-1668	9	44.7	1903-1910	8	27.2
10	1580-1598*	9	32.2	1962-1969	8	26.1
11	1852-1857	6	29.7	1773-1779	7	24.4
12	1956-1961	6	29.6	1832-1842	11	21.1
13	1467-1472*	6	27.0	1726-1733	8	21.0
14	1377-1388*	12	26.3	1943-1947	5	20.6
15	1637-1640	4	24.8	1641-1645	5	19.5

Source: Bunkers, M.J., L.R. Johnson, J.R. Miller, and C.H. Sieg. 1999. Old Black Hills Ponderosa Pines Tell a Story. *Proceedings of the South Dakota Academy of Science*, Vol. 78.
Note: *Sample size <5 trees and is likely not adequate to reliably infer precipitation patterns.

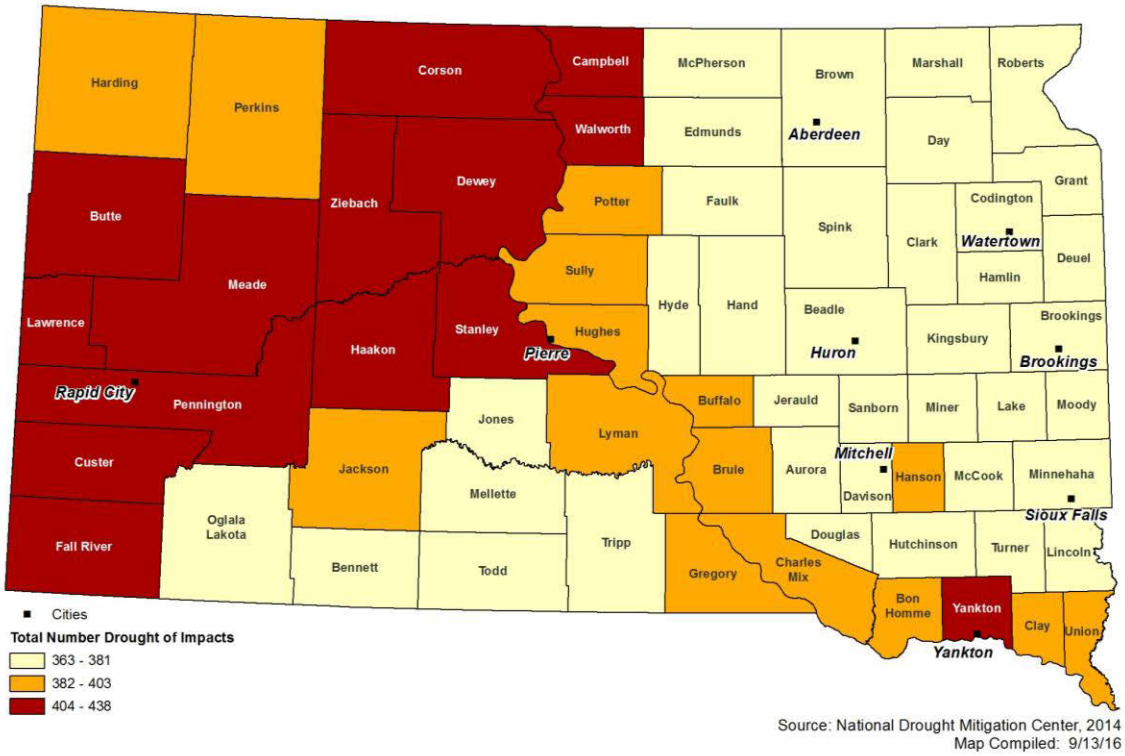
The National Drought Mitigation Center's Drought Impact Reporter contains information on 380 drought impacts from droughts that affected South Dakota between January 1, 1980 and July 2016. Figure 3-25 shows the distribution of drought impacts among South Dakota's counties. Corson, Campbell, Dewey, Walworth, and Pennington counties have experienced the most drought impacts according to the map. Most of the impacts, 172, were classified as "agriculture." Other impacts include "energy" (5), "plants and wildlife" (36), "society and public health" (44), "water supply and quality" (60), "business and industry" (17), "fire" (48), "relief, response, and restrictions" (103), and "tourism and recreation" (4). These categories are described as follows:

- **Agriculture**—Drought effects associated with agriculture, farming, aquaculture, horticulture, forestry, or ranching. Examples of drought-induced agricultural impacts include damage to crop quality; income loss for farmers due to reduced crop yields; reduced productivity of cropland; insect infestation; plant disease; increased irrigation costs; cost of new or supplemental water resource development (wells, dams, pipelines) for agriculture; reduced productivity of rangeland; forced reduction of foundation stock; closure/limitation of public lands to grazing; high cost or unavailability of water for livestock, Christmas tree farms, forestry, raising domesticated horses, bees, fish, shellfish or horticulture.
- **Business & Industry**—This category tracks drought's effects on non-agriculture and non-tourism businesses, such as lawn care, recreational vehicles or gear dealers, and plant nurseries. Typical impacts include reduction or loss of demand for goods or services, reduction in employment, variation in number of calls for service, late opening or early closure for the season, bankruptcy, permanent store closure, and other economic impacts.
- **Energy**—This category concerns drought's effects on power production, rates, and revenue. Examples include production changes for both hydropower and non-hydropower providers, changes

in electricity rates, revenue shortfalls and/or windfall profits, and purchase of electricity when hydropower generation is down.

- **Fire**—Drought often contributes to forest, range, rural, or urban fires, fire danger, and burning restrictions. Specific impacts include enacting or easing burning restrictions, fireworks bans, increased fire risk, occurrence of fire (number of acres burned, number of wildland fires compared to average, people displaced, etc.), state of emergency during periods of high fire danger, closure of roads or land due to fire occurrence or risk, and expenses to state and county governments of paying firefighters overtime and paying equipment (helicopter) costs.
- **Plants & Wildlife**—Drought effects associated with unmanaged plants and wildlife, both aquatic and terrestrial, include loss of biodiversity of plants or wildlife; loss of trees from rural or urban landscapes, shelterbelts, or wooded conservation areas; reduction and degradation of fish and wildlife habitat; lack of feed and drinking water; greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant of the intrusion; disease; increased vulnerability to predation (from species concentrated near water); migration and concentration (loss of wildlife in some areas and too much wildlife in others); increased stress on endangered species; salinity levels affecting wildlife; wildlife encroaching into urban areas; and loss of wetlands.
- **Society & Public Health—**Drought effects associated with human, public and social health include health-related problems related to reduced water quantity and/or quality, such as increased concentration of contaminants; loss of human life (e.g. from heat stress, suicide); increased respiratory ailments; increased disease caused by wildland fire concentrations; increased human disease caused by changes in insect carrier populations; population migration (rural to urban areas, migrants into the United States); loss of aesthetic values; change in daily activities (non-recreational, like putting a bucket in the shower to catch water); elevated stress levels; meetings to discuss drought; communities creating drought plans; lawmakers altering penalties for violation of water restrictions; demand for higher water rates; cultural/historical discoveries form low water levels; prayer meetings; cancellations of fundraising events; cancellation/alteration of festivals or holiday traditions; stockpiling water; public service announcements and drought information websites; protests; and conflicts within the community due to competition for water.
- **Tourism & Recreation—**Drought effects associated with recreational activities and tourism include closure of state hiking trails and hunting areas due to fire danger; water access or navigation problems for recreation; bans on recreational activities; reduced license, permit, or ticket sales (e.g. hunting, fishing, ski lifts, etc.); losses related to curtailed activities (e.g. bird watching, hunting and fishing, boating, etc.); reduced park visitation; and cancellation or postponement of sporting events.
- **Water Supply & Quality**—Drought effects associated with water supply and water quality include dry wells, voluntary and mandatory water restrictions, changes in water rates, easing of water restrictions, increases in requests for new well permits, changes in water use due to water restrictions, greater water demand, decreases in water allocation or allotments, installation or alteration of water pumps or water intakes, changes to allowable water contaminants, water line damage or repairs due to drought stress, drinking water turbidity, change in water color or odor, declaration of drought watches or warnings, and mitigation activities.

Figure 3-25: Drought Impact Distribution in South Dakota: 1980-2015



Source: National Drought Mitigation Center Drought Impact Reporter

NCDC reported 297 drought events affecting 46 counties and/or zones in South Dakota since 2012. No damages or casualties were recorded for these events. Table 3-13 summarizes some of the most severe droughts in the State since 1889.

Table 3-20: South Dakota Droughts: 1889-2016

Date	Comments
January-June 2013	Drought conditions continued over all of southeast South Dakota in January. Precipitation was below to well below normal, although with the low midwinter normals, even greater precipitation would have been unlikely to change the dry soil conditions. There was little noted in the way of new effects of the drought, with the dry conditions giving a poor outlook for the Spring and Summer, including poor germination of the winter wheat crop during the dry fall. Water restrictions continued to be few during the winter because of the low water usage, but the area was becoming more vulnerable to even marginally weather if it developed in the spring and summer. Drought was generally listed as continued severe to extreme for the area.
October 2012	Drought conditions continued over all of southeast South Dakota in October with well below normal rainfall keeping soil and vegetation dry. Rainfall for the month was below normal everywhere, and less than half of normal in much of the area. Harvest of drought affected crops was completed, but there was no estimation available on how much yields were reduced. Winter wheat was planted on time, but the lack of moisture greatly hampered germination. Water restrictions were generally eased, with water use dropping off with the fall season. Drought was generally listed as continued severe to extreme for the area.

Date	Comments
September 2012	Drought conditions continued over all of southeast South Dakota with well below normal rainfall keeping soil and vegetation dry. Rainfall for the month varied from around half to less than a quarter of normal. Stress on crops that prevailed over the growing season became more evident with the start of harvest, although the amount of the reduced yields was still uncertain. Local governments continued to use water use restrictions in an effort to prevent serious water supply problems. Drought was generally listed as continued severe to extreme for the area.
August 2012	Drought conditions continued over all of the area with below normal rainfall keeping soil conditions dry. Stress on crops continued even though August was less hot than July, with temperatures averaging only a little above normal. Crop damage was quite evident, though the amount of reduced yields and other damage which might become evident at harvest was uncertain. While reported water supply problems were not extreme, many local governments had water use restrictions in place. Drought was generally listed as severe to extreme for the area, and was being compared to the worst of the dust bowl years, though not yet over as long a time period.
July – August 2012	Drought conditions became established over much of the State with long term dry climate and soil conditions combining with much below normal rainfall during the month. Stress on crops increased and was continuous with no significant relief during the dry month. Hot weather added to the stress as it contributed to high evaporation. Crop damage in the form of reduced yields became certain, but the long remaining time to harvest and the unknown rainfall before that time made even rough damage estimates impossible. Severe general long term non-agricultural water supply problems were not observed, but the continued long term dry conditions raised fears of this for the future. Cattle sell-off's were also occurring across the region. Range and pasture conditions were poor to very poor with fire danger remaining a big issue. The severe drought continued into August.
June 2012	Long term dry climate and soil conditions combined with well below normal rainfall to make the dry conditions more acute and short term. This resulted in stress on crops developing during the month, mainly south of Interstate 90. After an abnormally dry fall and winter, short term drought fears had been temporarily forestalled by spring rains. The rains had fallen shortly after an unusually early planning brought on by very warm late winter and early spring weather. However, the return to dry weather in June compounded the effects of the long term dry conditions.
January – March 2012	The severe drought conditions from December continued across part of northeast South Dakota including the counties of Deuel, Codington, and Hamlin throughout March. The severe drought conditions would continue into February.
2007	Drought continued in some areas of South Dakota. The July 24, 2007, Drought Monitor for South Dakota (Figure 3-22) showed that drought encompassed most of the state. Most of Fall River County was experiencing severe drought conditions that also reached north into southern Custer County.
2006	Fifty-six counties designated primary natural disaster areas by the USDA. The other 10 were contiguous to primary natural disaster areas and thus also eligible for assistance. For many areas, this was their seventh consecutive year of drought. The National Weather Service cooperative observer 8 miles north-northwest of Usta in Perkins County recorded a maximum temperature of 120 degrees on July 15th, which tied the previous all-time record high in South Dakota, first set on July 5th, 1936 in Gann Valley. A woman died of heat exhaustion while hiking in the

Date	Comments
	Badlands National Park on July 16th.
2005	Fifteen counties designated primary natural disaster areas by the USDA. Twenty nine were contiguous to primary natural disaster areas and thus also eligible for assistance. In 2005, the Missouri River basin had experienced five consecutive years of below normal runoff. System storage was at a record low due to the combined impact of the drought and water allocation decisions made during the drought. Impacts included reduced hydropower production, loss of fish production, unusable boat ramps, and irrigation water supply problems. Source: South Dakota Engineer Society
2004	Thirty-four counties designated primary natural disaster areas by the USDA. Eighteen were contiguous to primary natural disaster areas and thus also eligible for assistance.
2003	Forty-three counties designated primary natural disaster areas by the USDA. Twenty were contiguous to primary natural disaster areas (in South Dakota or neighboring states) and thus also eligible for assistance.
2002	Many areas in South Dakota were devastated by drought in 2002. After a dry winter and spring, below normal rainfall for June brought severe drought conditions to the area. Much of the rainfall for June was below 50 percent of normal with much of the area receiving 20 to 40 percent of the normal rainfall. Some locations were at 10 to 15 percent of normal rainfall. Central and north central South Dakota were the hardest hit with the drought conditions. As a result of the severe dryness, a lot of grazing land and stock ponds dried up, and ranchers had to buy additional feed for their animals, transport them to healthier pastureland for grazing, or sell their herds prematurely. Crops suffered with much having to be cut up for hay or replanted. Water levels on lakes and rivers were also way down. Burn bans and voluntary or mandatory water restrictions were implemented across much of the area. All counties were declared drought disasters.
May/July 1992	Twenty-eight counties declared by governor as drought disaster areas: Aurora, Bon Homme, Buffalo, Butte, Campbell, Charles Mix, Corson, Dewey, Douglas, Edmunds, Haakon, Hand, Harding, Hughes, Hyde, Jackson, Jerauld, Jones, Lawrence, Lyman, Meade, Perkins, Stanley, Sully, Todd, Tripp, Walworth, and Ziebach.
1988	Statewide. Regional impact varied.
1985–1987	Western half of state during 1985; continued in Black Hills during 1986 and 1987. Rated as a 10- to 25-year event.
1980–1982	Statewide. Rated as a 10- to 25-year event. Most severe in 1981.
1973–1977	Statewide, except Black Hills. Rated as a 10- to 25-year event. Most severe in 1976. Includes drought emergency declaration (FEMA-3015-EM) in 1976.
1954–1962	Statewide. Rated as a 25-year event. Regional variations. Most severe in 1956 and 1959, except in the Black Hills where it was most severe in 1961.
1929–1942	Statewide. Rated as greater than a 25-year event. Dust Bowl years. Regional impact varied a little. Most severe in 1931, 1933, 1934, and 1936. Included in this period was a “plague” of grasshoppers.
1910–1914	Western half of state. Regional impact varied. Most severe in 1911.
1889–1905	Statewide. Regional impact varied. Most severe between 1894 and 1896 and 1898 and 1901.

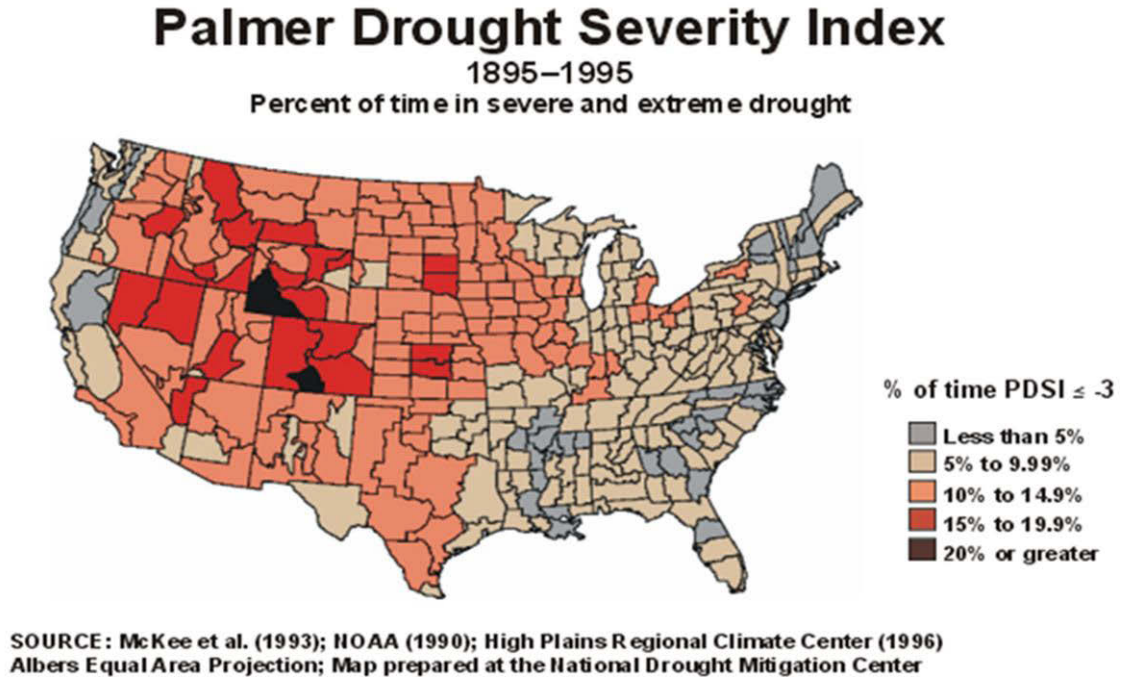
Source: NCDC

Data on indemnity payouts for crop loss due to drought and high heat between 2010 and 2012 was obtained from the Risk Management Agency. In 2012, the State received $838,876,036 for crop loss due to drought and $47,640,782 due to heat, for a total of $886,516,818. This contrasts sharply with the indemnity payments in 2011 and 2010, both of which were wet years. In 2011, the State received $9,879,016 for crop losses from heat and $4,766,416 for drought for a total of $14,555,432. In 2010, the State received $4,985,132 for crop losses from drought and $2,110,751 for heat, for a total of $7,095,883. Clearly, severe drought years can have a devastating financial impact on South Dakota's agricultural industry.

Probability

Figure 3-25 from the NDMC website, illustrates that most of South Dakota has experienced severe or extreme drought between 15 and 19.9% of the time over a 100-year period. Based on the tree ring research noted previously, which spans a period of roughly 400 years, multi-year droughts as significant as the 1930's drought or worse occur on average every 57 years. Based on historical records (10 in the past 118 years, counting the 2002-2007 dry spell and other multi- year events as one event) notable droughts have occurred somewhere in the state on average about every 12 years, which is equivalent of an 8% chance any given year. Climate change could increase the frequency of drought in South Dakota in the future. The next section discusses climate change as it relates to the probability of future droughts and its general implications for the State.

Figure 3-26: United States: Percent of Time in Drought, 1895-1995



Climate Change Considerations

The National Climate Assessment provides an in-depth look at climate change impacts on the U.S on a regional basis (http://nca2014.globalchange.gov/report). South Dakota is part of the Great Plains region which includes the states of Kansas, Montana, Nebraska, North Dakota, Oklahoma, Texas, and Wyoming. The science summarized in the report points to increasing mean temperatures in the Great Plains. This will lead to increased evaporation and drought frequency, which will compound water scarcity problems. In parts of the region, this will constrain development, stress natural resources, and increase competition for water among communities, agriculture, energy production, and ecological needs. Communities that are already the most vulnerable to weather and climate extremes will be stressed even further by more frequent extreme events occurring within an already highly variable climate system. Changing extremes in precipitation are projected across all seasons, including higher likelihoods of both increasing heavy rain and snow events and more intense droughts. The Northern Plains will remain vulnerable to periodic drought because much of the projected increase in precipitation is expected to occur in the cooler months while increasing temperatures will result in additional evapotranspiration.

In regards to temperatures and extreme heat, warmer and more extreme temperatures can exacerbate drought impacts and result in consequences regardless of drought. According to the National Climate Assessment, for an average of seven days per year, maximum temperatures reach more than 100ºF in the Southern Plains and about 95ºF in the Northern Plains. These high temperatures are projected to occur much more frequently, even under a scenario of substantial reductions in heat-trapping gas (also called greenhouse gas) emissions, with days over 100ºF projected to double in number in the north of the great plains region and quadruple in the south by mid-century. These increases in extreme heat will have many

negative consequences, including increases in surface water losses, heat stress, and demand for air conditioning.

Tornado

Description

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service defines a tornado as a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph or more. Damage paths can be in excess of one-mile wide and 50 miles long. In an average year, about 1,000 tornadoes are reported across the United States, resulting in approximately 80 deaths and more than 1,500 injuries.

Though climate data is available to explain a predisposition to tornadoes, there is no accurate way of predicting when or where a tornado may occur. Tornado systems have been linked to the development of temperature and wind flow patterns in the atmosphere, which can cause moisture, instability, lift, and wind shear (NOAA). Expert predictions of these conditions begins first by modeling in the long term and relying on critical analysis of satellite data, weather stations, balloon packages, airplanes, wind profilers, and radar-derived winds to pinpoint storm activity for the short term (NOAA).

Tornadoes typically occur in South Dakota in May, June, and July, but they can occur in any month. The greatest period of tornado activity (about 82 percent of occurrence) is from 11 a.m. to midnight. Within this time frame, most tornadoes occur between 4 pm and 6 pm.

Prior to February 1, 2007, tornado intensity was measured by the Fujita (F) scale. This scale was revised and is now the Enhanced Fujita scale. Both scales are sets of wind estimates (not measurements) based on damage. The new scale provides more damage indicators (28) and associated degrees of damage, allowing for more detailed analysis, better correlation between damage and wind speed. It is also more precise because it takes into account the materials affected and the construction of structures damaged by a tornado. Table 3-21 shows the wind speeds associated with the original Fujita scale ratings and the damage that could result at different levels of intensity. Table 3-22 shows the wind speeds associated with the Enhanced Fujita Scale ratings. The Enhanced Fujita Scale's damage indicators and degrees of damage can be found online at www.spc.noaa.gov/efscale/ef-scale.html.

Table 3-21: Original Fujita Scale

Fujita (F) Scale	Fujita Scale Wind Estimate (mph)	Typical Damage
F0	< 73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73-112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113-157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158-206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207-260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261-318	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena will occur.

Source: National Oceanic and Atmospheric Administration Storm Prediction Center, www.spc.noaa.gov/faq/tornado/f-scale.html

Table 3-22: Enhanced Fujita Scale

Enhanced Fujita (EF) Scale	Enhanced Fujita Scale Wind Estimate (mph)
EF0	65-85
EF1	86-110
EF2	111-135
EF3	136-165
EF4	166-200
EF5	Over 200

Source: National Oceanic and Atmospheric Administration Storm Prediction Center, www.spc.noaa.gov/faq/tornado/ef-scale.html

Location

Tornado disasters are often associated with Tornado Alley (the area from the Gulf to the Northern Great Plains that has high tornado incidence). South Dakota sits in the northern region of Tornado Alley and is susceptible to the specific conditions to which the formation of tornadoes has been attributed: warm Gulf air coming in contact with cool Canadian air fronts and dry air systems from the Rocky Mountains. The intersection of these three systems produces thunderstorm conditions that can spawn tornadoes. According to NOAA, tornadoes can occur at any location and from a wide variety of conditions. Western South Dakota, though not in the Tornado Alley, is still vulnerable to tornadoes of different strengths.

Figure 3-27 illustrates the number of F3, F4, and F5 tornadoes recorded in the United States per 2,470 square miles between 1950 and 2006. Figure 3-28 illustrates the wind zones in the United States. By

noting the South Dakota data from these two maps and matching them up in Table 3-23, it appears that approximately 90 percent of South Dakota has a high tornado risk and 10 percent has a moderate tornado risk. A very small area in the northwest corner of the state has a low tornado risk.

Figure 3-27: Tornado Activity in the United States

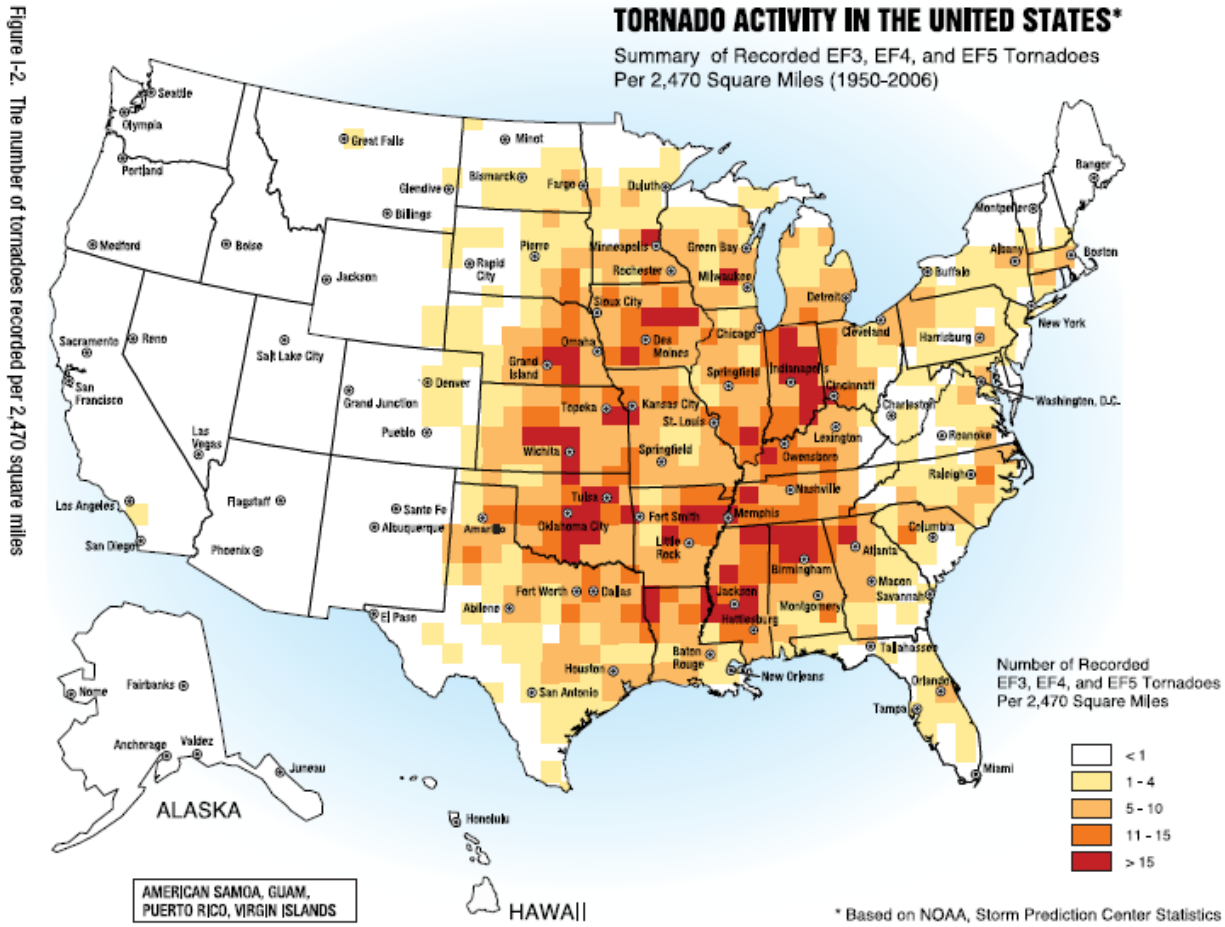


Figure I-2. The number of tornadoes recorded per 2,470 square miles

Source: Taking Shelter from the Storm (FEMA 2008)

Figure 3-28: Wind Zones in the United States

Source: Taking Shelter from the Storm (FEMA 2008)

Table 3-23: Wind Zones

Number of Tornadoes Per 2,470 square miles (See Figure 3-27)	Wind Zone (See Figure 3-28)			
	I	II	III	IV
<1	Low Risk	Low Risk	Low Risk	Moderate Risk
1-4	Low Risk	Moderate Risk	High Risk	High Risk
5-10	Low Risk	Moderate Risk	High Risk	High Risk
11-15	High Risk	High Risk	High Risk	High Risk
>15	High Risk	High Risk	High Risk	High Risk

Source: Taking Shelter from the Storm (FEMA 2008)

Past Events

According to the National Climatic Data Center (NCDC) Storm Events database, there were 636 tornadoes in South Dakota between 1950 and July 2016 rated as an F1 or higher. Tornadoes reported in the database are in segments. One tornado can have multiple segments as the NCDC counts a new segment when county boundaries are crossed. So, the number of past occurrences is really a reflection of the number of past tornado segments. Total property damage for these events is estimated at $688 million. There were 17 deaths and 456 injuries in this time period. This number increases to 18 deaths and 465 injuries if all tornado events, including those smaller than an F1, are recorded. This suggests that South Dakota experiences 10 tornadoes of F1 intensity or greater, $10,967,741 in damages, and seven injuries each year. See Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction for more information about how tornadoes affect individual counties. Figure 3-29 shows the number of tornadoes by county between 1950 and 2012. Figure 3-30 shows tornado paths of individual tornadoes where data was available.

Figure 3-29: South Dakota Tornadoes by County, 1950-2016

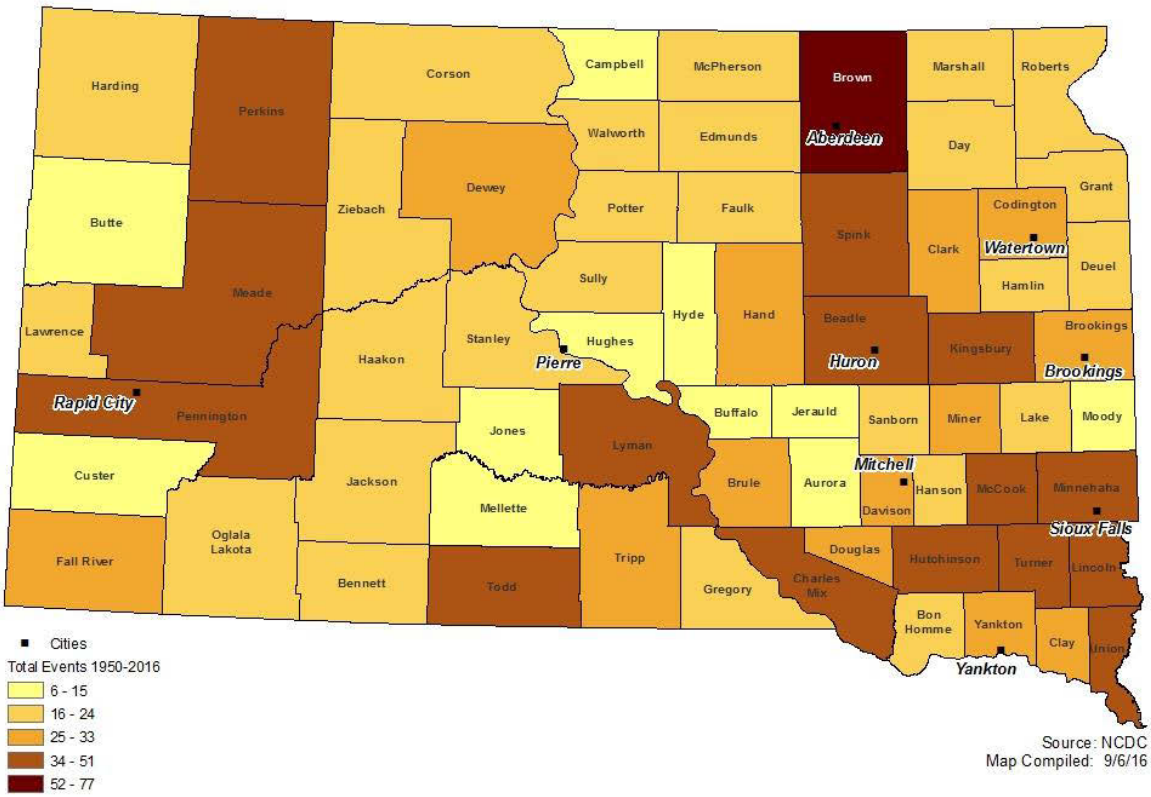


Figure 3-30 Tornado Paths in South Dakota 1953-2016

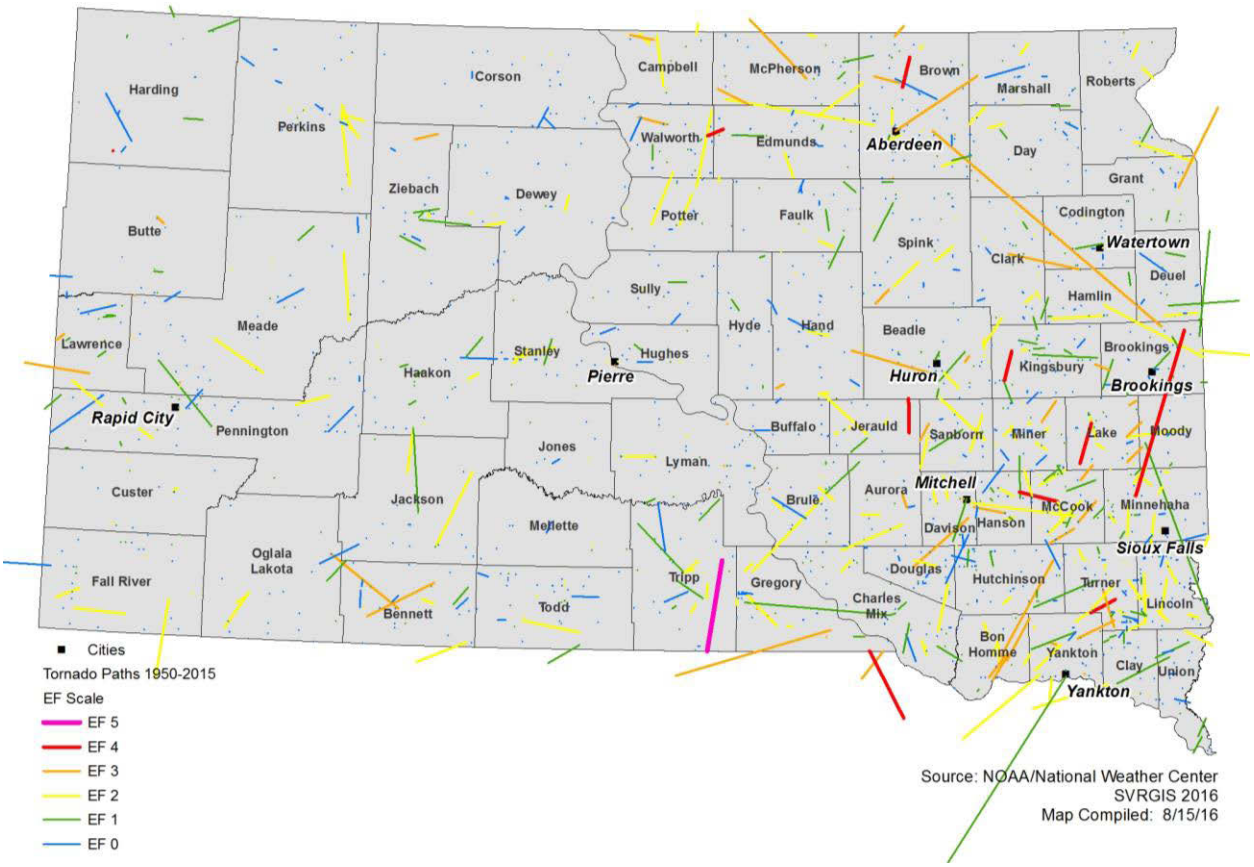


Table 3-24: South Dakota Tornadoes

Date	Comments
August 6, 2015	Thunderstorms produced damaging winds in southeast South Dakota during the afternoon and early evening of August 6th. The storms affected mostly Brookings County, but the first report was some distance away in Gregory County, and there were reports in Moody County also. There were also two tornadoes and one report of large hail. A tornado damaged the roof, gutters, and siding of three houses, damaged the roof, patio deck, chimney, and garage of another house, and damaged a fence. Damages estimated at $80,000.
June 19, 2015	A long-lived complex of severe thunderstorms tracked from southeastern Montana across northwestern South Dakota. The strongest storms produced hail to six inches in diameter, wind gusts over 80 mph, and a tornado in southern Meade County. Significant structure, property, and crop damage was reported in Butte and Meade Counties. Livestock were killed by the large hail in the Nisland area, with one rancher losing 35 sheep. The storms continued into south central South Dakota, but no reports were received due to a widespread power outage. A tornado touched down in rural southern Meade County, damaging buildings and tossing equipment at two ranches. Damage estimated at $100,000.
May 10, 2015	Thunderstorms over southeast South Dakota from late morning to the start of the evening on May 10th produced several tornadoes, including one that caused injuries

Date	Comments
	and severe damage in Delmont in Douglas County. The thunderstorms also produced large hail, damaging winds, and flash flooding in locations extending to the eastern border of the state. A tornado, crossing into Douglas County from Charles Mix County, destroyed or damaged 84 structures in and near Delmont, and injured 9 people in Delmont. About 50 of the homes and other structures were destroyed or severely damaged. The damage included numerous small farm buildings totally destroyed, most at four farms south of Delmont, several houses severely damaged, a large and 100 year old church severely damaged, and a newly constructed fire hall destroyed. Power lines and poles were down and the town was without power and water for two days. 100 residents were displaced. Damages estimated at $1.5 million.
June 18, 2014	Thunderstorms during the evening of June 18th produced tornadoes in Jerauld County, with one tornado crossing briefly into Beadle County. The tornadoes included one that caused severe damage to Wessington Springs. There was also a report of large hail. A tornado severely damaged two family farms, including destroying a farmhouse as the family took shelter in their basement. A couple in the house suffered minor injuries. The tornado also damaged trees, power poles, and power lines; and caused an unknown amount of crop damage. The tornado crossed briefly into Beadle County before lifting. Damage estimated at $325,000.
June 17, 2014	Thunderstorms during the late evening of June 17th produced a tornado near Humboldt South Dakota in Minnehaha County and large hail near Dolton in McCook County. The tornado blew down the exterior walls of a house, in which a family escaped injury by taking shelter in the basement. The tornado also tore the roof off a farm storage building, tore the metal roof off a metal building, blew down electrical poles, and caused tree damage, including several trees snapped off at the trunks. Damage estimated at $100,000.
October 4, 2013	A tornado crossed the Missouri River from Dakota County in Nebraska and entered Union County. The tornado severely damaged the roof of a house, and collapsed a chimney, carport and porch roof, and the walls of a garage in the same house. The tornado also caused tree damage, including trunks snapped, overturned an irrigation system, and damaged the roof, siding, and/or gutters of at least four other houses. Damage estimated at $450,000.
May 28, 2013	A tornado touched down on the west side of Allen Road south of Allen and rolled a mobile home down a hill. It tore off the roof and collapsed several walls of a small stick built house on the east side of the road before dissipating. Damage was estimated at $100,000.
June 22, 2012	A severe thunderstorm tracked eastward from Wyoming across southern Fall River County. The storm produced enormous hail near Edgemont and a tornado between Edgemont and Ardmore. The tornado damaged buildings on a ranch north of Ardmore and blew down power poles and trees. A large wooden barn was completely destroyed; its walls and roof were blown more than 100 yards away. Two large sheds lost roofs and walls, and smaller sheds were blown apart. A modular house sustained minor damage. Damage was estimated at $500,000.
June 12, 2011	A cluster of severe thunderstorms moved east from northeastern Wyoming and southeastern Montana across Harding and Butte counties. The storms produced hail, wind gusts near 80 mph, and a small tornado west of Redig. The tornado destroyed part of a barn, rolled large steel calf shelters, blew down steel stockade walls, and lifted a calf shelter over a nine foot fence.

Date	Comments
May 9, 2011	A severe thunderstorm produced a tornado northeast of Wall and wind gusts to 60 mph over far eastern Meade County. A large electric transmission tower was crumpled, seven wooden power poles were snapped, and trees were snapped.
June 16, 2010	**FEMA-1929-DR** An intense low pressure system developed across the northern Plains states and impacted the region on June 17. At least 61 tornadoes were reported that afternoon and evening across North Dakota, South Dakota, and Minnesota. A supercell around Dupree and Faith spawned 16 or more tornadoes, with 4 and possibly 5 on the ground at the same time.
May 22, 2010	Severe weather shifted north as a low pressure system tracked across the northern Plains states on May 22. Isolated tornadoes were reported across portions of central South Dakota that afternoon. The most intense supercell produced a long-lived wedge tornado in and around Bowdle, South Dakota where numerous houses and farm buildings were destroyed and cars were thrown into the air. It was rated as an EF4, but fortunately remained in rural areas and no injuries were reported. Tornadoes in Edmunds and McPherson counties damaged 60 utility poles. FEM Electric customers on 40 meters were without power for 48 hours. Emergency repair and restoration costs for FEM Electric were estimated at $210,000.
July 9, 2009	Severe storms developed over Fall River County and moved eastward across southwestern and south central South Dakota. The storms produced large hail and strong wind gusts. Two tornadoes were observed in Todd County and two tornadoes touched down in southern Tripp County. A small tornado touched down on a farm west of the intersection of 286th Street and 313th Avenue. The tornado blew a garage off its foundation, tipped over a combine, and snapped large cottonwood trees.
May 12, 2009	An F1 tornado travelled for eight miles with a width of 200 yards. The tornado touched down west of Dupree and tracked eastward before dissipating northeast of Dupree. It dented several grain bins, blew over a small mobile home and semi-trailer truck, tore sheet metal off sheds, and toppled a large communications tower.
June 5, 2008	An F1 tornado 100 yards wide damaged a path ten miles long. The tornado severely damaged a home, destroyed outbuildings, and damaged storage bins at a farm near Ravinia. The tornado also caused tree damage along its path. An F2 tornado caused damage to silos, farm buildings, power lines, and numerous trees southeast of Baltic.
May 29, 2008	An F-1 Tornado two miles long and 100 yards wide destroyed a barn, damaged or destroyed several outbuildings, scattered lumber across a field, and damaged trees and power lines. Damages were estimated at $100, 000.
May 5, 2007	**Severe Storms, Tornadoes, and Flooding (FEMA-1702-DR)** Twenty-five tornadoes were recorded in southeast South Dakota. It was the most significant tornado outbreak in southeast South Dakota since June 24, 2003. The strongest tornado, an EF-3, occurred in Aurora County. On the ground for five miles, it did its most significant damage to a pheasant hunting lodge/preserve, where numerous buildings and trees were severely damaged and numerous adult and chick pheasants were lost. Winds were estimated at around 140 mph. In Bon Homme County, an EF-2 tornado was on the ground for six miles, severely damaging many homes, barns, out-buildings, and trees. An EF-2 tornado traveled through both McCook and Hanson Counties and was observed to be very large before it dissipated. Most of the damage was to trees and a

Date	Comments
	junk yard. In western Hanson County, an EF-1 tornado damaged trees and took a roof off a building. In Yankton County, a tornado began at the Lewis and Clark Recreation Area and resulted in considerable tree damage and damage to homes. It was on the ground for approximately four miles. For a while, it was joined by a second tornado. These tornadoes were determined to be EF-1s based on the damage homes. High winds related to these storms damaged power distribution lines and poles in Bon Homme and Yankton counties. Seven poles were damaged in Bon Homme County for a total of $13,014 in damages. Twenty-five poles were damaged in Yankton County for $34,809 in damages. 20 outages affected 214 customers, leaving them without power for roughly 9 hours. Source: NWS Sioux Falls and SHMT
September 16, 2006	Seven tornadoes touched down over southeast South Dakota. The strongest, an F2, was in McCook County and damaged several buildings and killed several cattle. An F1 tornado in Minnehaha County damaged some buildings and downed power lines. There was no damage reported from the other storms (F0s). Source: NWS Sioux Falls
August 26, 2006	Severe weather in east central South Dakota produced at least three tornadoes. In Beadle County, two tornadoes did considerable damage to farmsteads, power lines, and crops. One was a 24.5 mile long-track F2/F3 tornado with winds up to 200 mph that measured between 400 and 500 yards at its widest. Another tornado touched down in Kingsbury County, but did little to no damage. Source: NWS Sioux Falls
May 2, 2006	An F1 tornado touched down in Kingsbury County. While the tornado was generally F0, there were a couple of periods where it approached F1 intensity. It hit a hog operation, destroying a barn and two other outbuildings, downing several trees, and killing numerous hogs. Source: NWS Sioux Falls
June 24, 2003	Sixty seven tornadoes touched down in South Dakota on this day. This rare occurrence tied the U.S. record at the time for the most tornadoes within a state in a 24-hour time period. However, the 67 tornado touchdowns recorded that day occurred in a period of less than eight hours. The strongest of the 67 tornadoes was an F4, which destroyed the town of Manchester and injured five people. Winds were estimated to be between 207 and 260 mph. The tornado warning issued by the National Weather Service in Sioux Falls provided the residents of Manchester with 28 minutes of advance warning. The National Weather Service offices in Aberdeen and Sioux Falls issued more than 350 warnings, statements, and storm reports on the evening of June 24. The 67 tornado touchdowns recorded that day represented a significant portion of the 85 total tornado touchdowns recorded for all of 2003. Despite the historic events of this day and the destruction of the town of Manchester, no presidential disaster declarations were issued.
June 23, 2002	Four separate tornado tracks and two satellite tornadoes were confirmed across McPherson and Brown counties. The first was an F0, the second an F1, the third and F3, and the fourth an F4. This was the first F4 tornado recorded in Brown County. Source: NWS Aberdeen
July 27, 2001	In Lincoln County, an F1 tornado downed numerous trees and damaged storage sheds and buildings along Main Street in Lennox, including the VFW (Veterans of Foreign

Date	Comments
	Wars). Source: NWS Sioux Falls
July 11, 2000	An F2 tornado hit Lake County and damaged the Lake County Speedway. Source: NWS Sioux Falls
June 4, 1999	**Severe Storms, Flooding, and Tornadoes (FEMA-1280-DR)** A deadly tornadic storm moved across southwest South Dakota during the late afternoon and evening of June 4. Multiple tornadoes (F1 and F2) were observed from several supercells that moved toward the northeast from west of Chadron, Nebraska, to near Kyle, South Dakota, between 5:30 and 8:00 p.m. The most severe damage occurred where the paths of these storms passed near the community of Oglala in Oglala Lakota County (previously Shannon County), South Dakota. Oglala was heavily impacted by the tornadoes as were other smaller communities on the Pine Ridge Indian Reservation. The Red Cross estimated that 123 homes sustained major damage and an additional 139 sustained minimal damage. FEMA deemed 49 homes beyond repair and demolished them. In one area, all of the telephone poles were snapped and tossed, mobile homes were thrown over 100 yards with debris strewn over a quarter of a mile, and a newly framed house was leveled with wood projectiles in the ground 100 yards downwind. The total Public Assistance damage for the disaster was $1,029,000. One person was killed and over 40 were injured; 22 required medical attention at area hospitals. The fatality was the first from a tornado in western South Dakota since 1939 and only the third ever recorded in western South Dakota. Very large hail was also reported in the area. Grapefruit-sized hail was observed two miles west of Oglala with golf ball and baseball-sized stones reported in Oglala itself.
May–June 1998	**Flooding, Severe Storms, and Tornadoes (FEMA-1218-DR)** By late afternoon of May 30, 1998, the atmosphere over the north central United States had become favorable to a significant outbreak of severe weather. At approximately 8:40 p.m., following a series of thunderstorm warnings and numerous funnel sightings in the area, a violent tornado struck the town of Spencer, South Dakota, approximately 45 miles west northwest of Sioux Falls in extreme western McCook County. Deemed the deadliest tornado in recorded South Dakota history, the F4 tornado killed 6 people, injured more than one-third of the town's 320 residents, and destroyed most of the town's 190 buildings, including all public and numerous private facilities. Only 12 structures were left standing in the entire town of Spencer. An assisted living center was destroyed, and since it had no basement, there was no protection from the tornado. Most of the fatalities were residents of the center. In addition to the town of Spencer, some farms in Hanson and McCook Counties were heavily damaged. Total damage was estimated at $18 million. During the storm, electrical service was out. Survivors reported that the warning siren system lost power prior to the touchdown of the tornado.
June 14, 1993	Pierre—Three homes damaged. No deaths. Arlington—Minor damage.
March 29, 1981	A winter storm front created a tornado near Martin, which destroyed a mobile home and injured one occupant.
May 12, 1984	Clark and Codington counties—18 to 20 farmsteads and homes were directly affected and ten homes severely damaged.
June 19, 1979	Watertown—Damage to trees, roofs, and power lines. Bon Homme, Turner, Yankton, Hanson, Sanborn counties—Tornado damage. Letcher—Tornado caused minor injuries with numerous reports of tree and building

Date	Comments
	damage. Springfield—Tree damage.
June 1978	Aberdeen—On June 15 and 16, Aberdeen and Marshall County experienced tornadoes, hail, and some flooding. Five trailers were damaged by tornadoes. Marshall County had crop and building damage from hail and tornado winds.
Summer 1977	Arlington—Minor damage.
July 23, 1973	Ft. Pierre/Pierre—The tornado began in Ft. Pierre where it did minor damage; one grain elevator and a few mobile homes were affected. It jumped the Missouri River and then "skipped" through Pierre. Houses and businesses were damaged and a few homes were completely destroyed. Many mobile homes were either scattered about or piled upon one another. No deaths. Ten people were injured. Damage amounted to over half a million dollars.
June 18, 1967	Rapid City—One motel suffered heavy structural damage along with several other buildings in the city. No deaths. Three people were injured. Over $2 million in damage was done.
May 21, 1962	Gregory County—Several homes were destroyed as was farm equipment, automobiles, and livestock. Many miles of power poles and lines were also knocked down. Damage exceeded $500,000. Mitchell—Damage was estimated at about $2 million to Mitchell and the surrounding countryside.
July 31, 1949	Beresford and Elk Point—A series of tornadoes struck the countryside between Beresford and Elk Point in the southeast corner of the state. Property damage exceeded $1 million.
June 29, 1947	Howard and Carthage—Occurred in the rural area of Howard and Carthage. Damage was light. A barn and airplane hangar were damaged. One death resulted.
June 12, 1947	Turner/Yankton counties—The rural area of Turner/Yankton counties was struck by a tornado that did hundreds of thousands of dollars in damage. Barns, houses, and sheds were destroyed, and crop damage was listed as heavy. There were no recorded deaths or injuries.
July 9, 1932	South of Sioux Falls (Minnehaha County)—One person died, 11 were people injured, and damage was estimated at $150,000. A number of horses and cattle were killed or injured, buildings were knocked down, and telephone and power lines were destroyed. This tornado was from a storm that also dropped baseball-sized hail throughout the area.

Source: NCDC, unless otherwise noted.

Probability

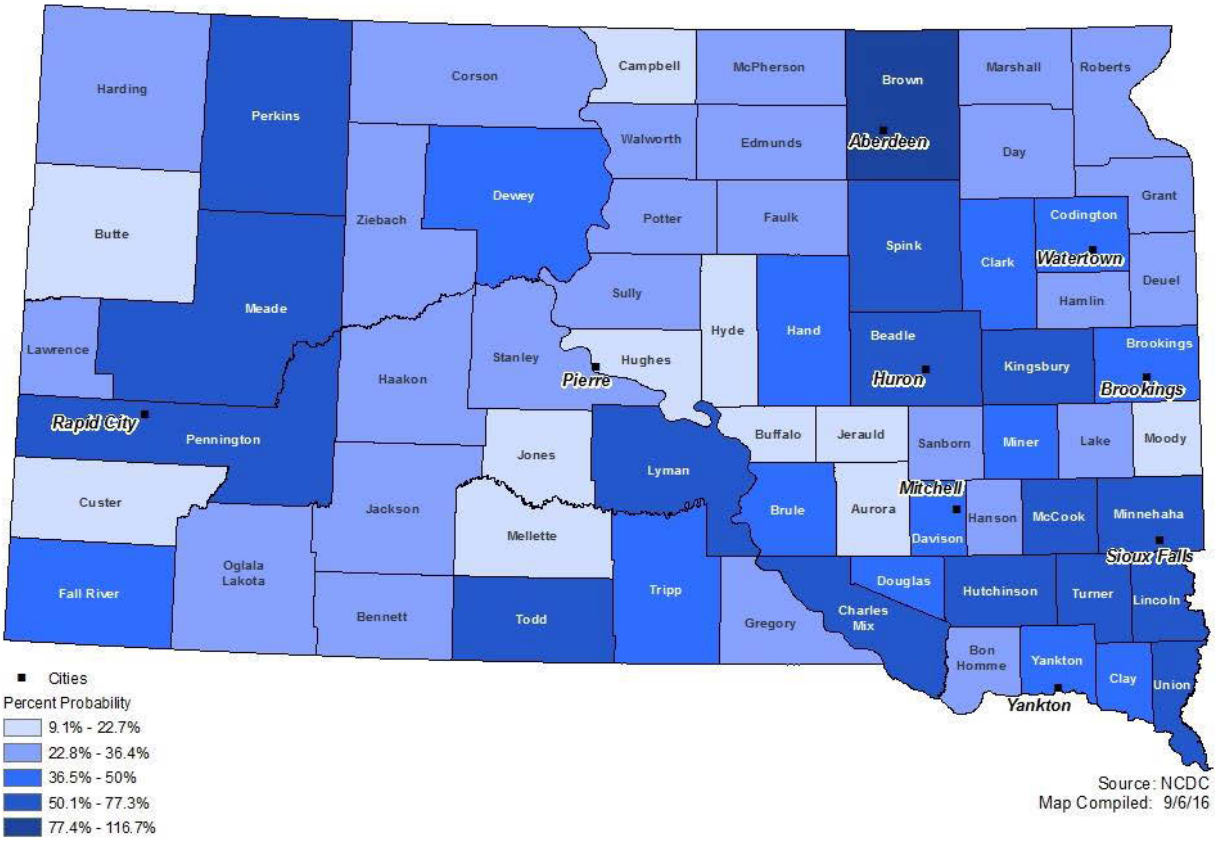
According to the National Climatic Data Center, there were 1,711 tornadoes, of which 636 were F1 or higher, in South Dakota between 1950 and 2016 (66 years). Based on this information, the probability that at least one tornado will occur in South Dakota is 100%. Annualized losses are estimated at nearly $11 million. Figure 3-31 depicts the probability of a damaging tornado occurring in each county based on the historical data.

Climate Change Considerations

There presently is not enough data or research to quantify the magnitude of change that climate change may have related to tornado frequency and intensity. NASA's Earth Observatory has conducted studies

which aim to understand the interaction between climate change and tornados. Based on these studies meteorologists are unsure why some thunderstorms generate tornadoes and others don't, beyond knowing that they require a certain type of wind shear. Tornadoes come from about 1 percent of thunderstorms, usually supercell thunderstorms that are in a wind shear environment that promotes rotation. As noted in the summer storm profile there are some studies that show a potential for a decrease in wind shear in mid-latitude areas. As there is a lot of uncertainty with the influence of climate change on tornadoes future updates to the mitigation plan should include the latest research on how the tornado hazard frequency and severity could change. The level of significance of this hazard should be revisited over time.

Figure 3-31 Damaging Tornado Probability by County



Windstorm

Description

Straight-line winds are generally any thunderstorm wind that is not associated with rotation (i.e., is not a tornado). It is these winds, which can exceed 100 mph, that represent the most common type of severe weather and are responsible for most wind damage related to thunderstorms. Since thunderstorms do not have narrow tracks like tornadoes, the associated wind damage can be extensive and affect entire (and multiple) counties. Objects like trees, barns, outbuildings, high-profile vehicles, and power lines/poles can be toppled or destroyed, and roofs, windows, and homes can be damaged as wind speeds increase. One type of straight-line wind is the downburst, which can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation.

Thunderstorms over the Northern Plains typically happen between late April and early September, but, given the right conditions, they can develop as early as March. They are usually produced by supercell thunderstorms or a line of thunderstorms that typically develop on hot and humid days.

Location

The entire state is susceptible to high wind events. Figure 3-28 in the tornado section above illustrates the wind zones in the United States. Most of South Dakota is in Zone III, which is vulnerable to winds up to 200 mph. The westernmost part of the state is in Zone II, which is susceptible to winds up to 160 mph.

Past Events

According to the National Climatic Data Center Storm Events database, there were 7,971 windstorm events (6,901 thunderstorm wind, 1,070 high wind, and 6 strong wind events) in South Dakota between 1955 and July 2016. There were 11 deaths and 136 injuries in this time period. Total property and crop damage for events between 1993 (when damage figures began being kept) and 2016 is estimated at $151,296,500 in 2016 dollars. This suggests that South Dakota could experience 272 wind events, $2,605,982 in wind losses, and approximately five injuries each year. See Section 3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction for more information about how wind affects individual counties. The map below shows the number of wind events by county between 1955 and 2016.

Figure 3-32: South Dakota Wind Events by County, 1955 – 2016

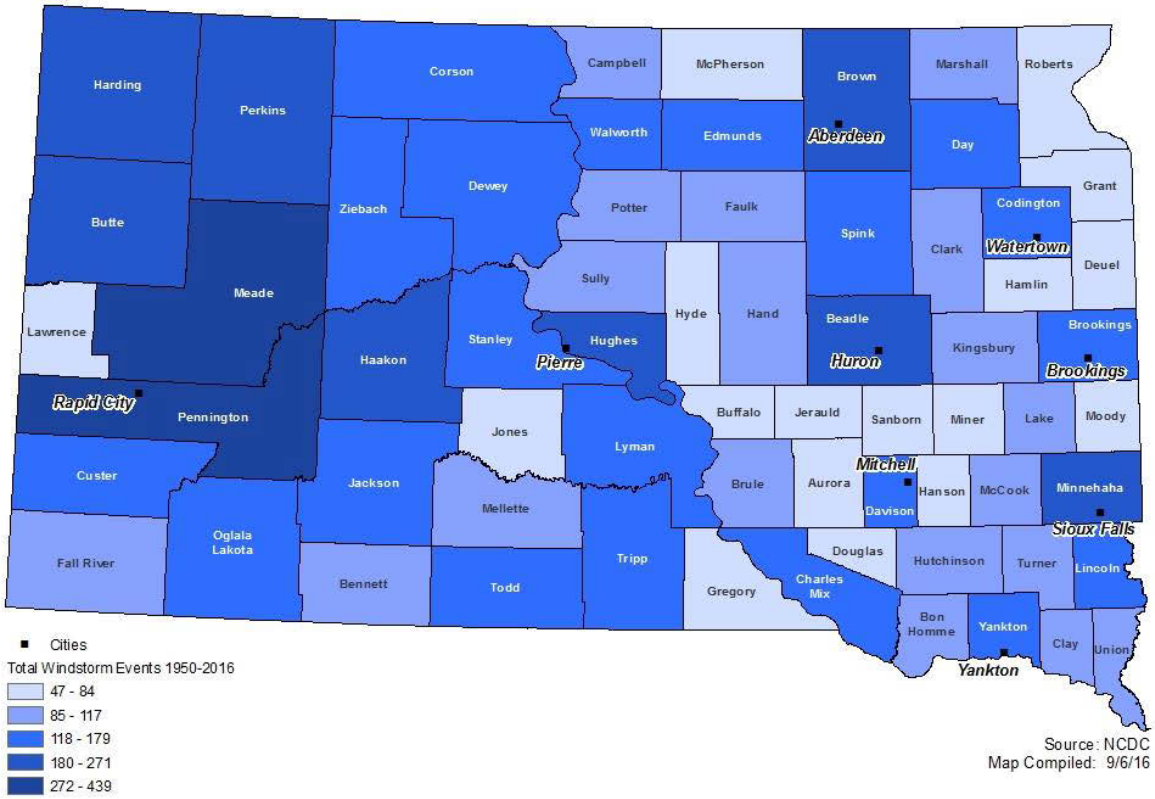


Table 3-25: South Dakota Wind Events

Date	Comments
February 18, 2016	A strong cold front crossed the region, bringing gusty northwest winds to much of western and south central South Dakota. Wind gusts from 60 to 80 mph accompanied the front late on the 18th into the nighttime hours. Wind gusts around 65 mph redeveloped on the 19th across portions of northwestern South Dakota and the Black Hills as a tight pressure gradient remained in place over the Northern Plains.
July 30, 2013	A long-lived supercell thunderstorm developed over western Haakon County and moved south-southeast across south central South Dakota. Very large hail was reported in some areas, along with strong wind gusts, and a small tornado near Philip. The wind-driven hail caused extensive damage to houses from Corn Creek to Parmelee. The combination of large hail and wind caused extensive damage to buildings and vehicles around town.
June 21, 2013	A strong warm front along with very unstable air and strong deep layer winds brought several supercell thunderstorms along with a damaging line of thunderstorms/bow echo to parts of central and northeast South Dakota during the afternoon hours. Damaging winds up to 90 mph uprooted large trees and caused considerable structural and crop damage and loss of power to those in its

Date	Comments
	path. The worst wind damage was located at Lake Poinsett, Watertown, and Milbank. A woman was killed and her husband was seriously injured on Lake Poinsett when their lake house was destroyed. Numerous trees were downed along with many structures damaged or destroyed. Many trees had fallen onto homes, cabins, and trailers. The bowling alley in Clear Lake lost its roof along with numerous pole barns being destroyed along the storm's path. Thousands of people were also left without power. Four tornado touchdowns occurred along with hail up to the size of softballs. Isolated flash flooding also occurred. Codington, Hamlin, Grant, and Deuel counties were all declared in a Federal Disaster Declaration. Total damage estimates were around 1,100,000 dollars.
May 28, 2013	A line of thunderstorms produced a small tornado that touched down briefly and strong straight line winds south of Allen. Straight-line wind damage was observed along BIA Road 22 southeast of Allen. The winds tore part of the roof off a small building and ripped shingles and metal roofing off two houses. A mobile home was rolled and completely smashed. A large cottonwood tree was snapped.
April 15, 2012	Very strong northerly winds affected southeast South Dakota during the evening of April 15th. Winds gusted to over 60 mph in parts of the area. A large outbuilding was destroyed near the western edge of Hitchcock, and a power pole standing in water was snapped off 4.5 miles east of Hitchcock.
April 2, 2012	A strong cold front passed through the region during the night. Strong north to northwest winds developed behind the front for several hours. The strongest winds occurred in the Rapid City area, where wind gusts to 65 mph were recorded. A semi-trailer was blown over on Interstate 90 six miles east of New Underwood.
April 30, 2011	A tight pressure gradient over the region resulted in strong northwesterly winds across western and central South Dakota. Sustained winds of 35 to 55 mph with gusts near 80 mph caused minor damage around Newell and Sturgis. The strongest winds were over the northwestern South Dakota plains. A large metal sign at a campground east of Sturgis was blown over. A pickup truck and travel trailer were flipped over south of Bear Butte.
June 10, 2010	Damaging winds, not directly from thunderstorms, affected the Madison to Brookings South Dakota area during the morning of June 10th. High winds severely damaged a barn. The winds also caused tree damage, with a playhouse damaged by tree debris. Vehicles were damaged by flying tree debris.
May 24, 2010	An intense low pressure system and cold front produced strong winds across southwestern South Dakota. Ahead of the low, strong south the southwest winds developed across south central South Dakota during the early afternoon. Behind the front, winds switched to the west across southwestern South Dakota in late afternoon. Sustained winds of 30 to 45 mph, with gusts to 70 mph, were recorded over much of the area. Some trees were downed by the wind. Minor damage occurred around the Hot Springs area.

Date	Comments
August 7, 2009	A super cell thunderstorm developed across the northern Black Hills and moved eastward across the Sturgis area, southern Meade County, northeastern Pennington County, Haakon County, and northeastern Jackson County. The storm produced baseball sized near Sturgis, then strong winds of 61 knots and hail larger than baseball sized developed as the storm moved across the plains. The storm hit Sturgis during the annual motorcycle rally and caused extensive damage to motorcycles, vehicles, and property. Minor injuries from the hail were also reported.
July 13, 2009	High winds developed behind an existing area of thunderstorms causing damage along with some injuries. Wind gusts to 50 to 70 mph were estimated or measured across parts of north central and northeast South Dakota. As a result, A mobile home was rolled twenty feet and destroyed by gradient winds associated with a wake low pressure area. The mobile home was not tied down and caught fire as it rolled into a propane tank. The three people inside the mobile home at the time all escaped with minor injuries.
October 26, 2008	Strong northwest winds reached sustained speeds of 40 mph or more with gusts to around 60 mph over all of southeast South Dakota during the morning and afternoon of October 26th.High winds sustained at 40 to 45 mph and gusting to over 60 mph caused damage to trees, shingles, and road signs. The tree damage included one very large weeping willow tree blown down in De Smet.
July 31, 2008	In the early morning hours of July 31st, a line of storms originating in North Dakota began to expand and surge southeast into northeast South Dakota. As the storms moved southeast, they began to tap into warmer, more humid air and rapidly evolve into a line of severe thunderstorms. Widespread damage occurred in a wide swath extending from Long Lake in McPherson County all the way into eastern Grant County and southern Big Stone County in Minnesota. The most extensive damage was generally found along and near US Highway 12 from Aberdeen to Milbank. Several observing stations in the path of this system measured wind speeds ranging from 70 mph to over 115 mph. Estimated wind speeds from damage surveys indicated even stronger winds with peak speeds of 120 mph. Over fifty communities in northeast South Dakota and the surrounding rural areas received minor to major tree and structural damage as straight line winds from 70 to 120 mph raced across the area. Webster and Waubay received the most extensive damage from the storms. Thousands of trees were snapped or uprooted, hundreds of grain bins were damaged or destroyed, hundreds of homes, businesses, and outbuildings were damaged or destroyed along with many power poles and miles of power lines downed. Many mobile homes, campers, and boats were damaged or destroyed along with many road and business signs. Countless homes, vehicles, and campers were also damaged by fallen trees. Thousands of acres of crops were also damaged or completely destroyed by the winds and hail. The greatest crop damage occurred in the

Date	Comments
	Roslyn, Grenville, Eden, and Pickerel Lake areas in Marshall and Day counties. Many acres of corn were blown down and not able to come back. The large hail combined with the strong winds also broke out countless windows in homes and vehicles along with damaging the siding on homes. Thousands of people were left without power for up to several days. Large hay bales were moved up to 700 yards by the high winds. A semi was overturned on Highway 12 near Webster, injuring the driver. Near Milbank on Highway 12, two other semis were blown off the road resulting in injuries to both drivers. A State Forestry Specialist said it was one of the worst tree damage events he has ever seen in the Webster area. A fifty-eight year old man died two miles north of Waubay during the cleanup after the storms when he was pinned between a backhoe and a tree.
June 26, 2008	On the evening of 26 June 2008, a compact upper level low pressure system tracking through the Northern Plains interacted with a very moist and unstable air mass over western and central South Dakota resulting in a widespread severe weather outbreak. Three confirmed tornadoes occurred briefly in western Dewey County. Little or no damage was reported and all three tornadoes were rated EF-0. In addition to the tornadoes, multiple reports of large hail were received over Corson and Dewey Counties, including some to the size of baseballs near the communities of McLaughlin and Isabel. The large hail broke out many home and vehicle windows and damaged many roofs in Dewey, Corson, and Sully Counties. Significant wind damage occurred over sections of Sully County. There were multiple reports of wind gusts in excess of 70 mph, with the most concentrated swath of damaging winds extending from near Sutton Bay, eastward to the city of Onida, then southeast to the community of Harrold. The storm survey began near Sutton Bay on Lake Oahe, where a wind gust of 92 mph was recorded. The most significant property damage was found further east near the community of Agar where multiple grain bins were either damaged or destroyed. Nine miles west of Agar, a barn was destroyed and a large pine tree was snapped in half. Winds in this area were estimated to range from 80 to 100 mph. Near the intersection of Highways 1804 and 175th Street, several Western Area Power Administration (WAPA) electrical transmission towers were completely collapsed. This is consistent with wind speeds ranging from 130-140 mph. In the city of Onida a bank roof was damaged and the city was without power until the next day. Four miles north of Onida, a feed wagon was tossed nearly 40 feet. In Harrold, several railroad cars were tipped over. Also of great significance during the event was the peak wind speed of 124 mph recorded at the Onida airport. This wind speed is the strongest wind gust ever

Date	Comments
	measured in the Aberdeen County Warning Area (CWA) and the 4th strongest wind speed ever reported in South Dakota
January 27, 2008	Strong southwesterly winds developed across the Black Hills during the afternoon and persisted through much of the night. Wind gusts of 60 to 70 mph were common across the higher terrain of the Black Hills and the northern and eastern foothills. The strongest winds were noted in the Spearfish and Hermosa areas, where a few gusts exceeded 90 mph. The strong winds caused a semi-trailer to jack knife on interstate 90 in Spearfish. Downed tree branches, signs, and damage to roofs were also reported around Spearfish.
July 9, 2007	Severe storms produced wind gusts to 80 mph across south central South Dakota. Roofs were torn off two houses and a trailer house was rolled three times. No injuries were reported. Damage estimates were reported at $75,000.
November 19, 2006	Strong southwest winds developed during the evening across parts of the northern Foothills. Winds gusted near 80 mph just west of Spearfish, while gusts over 50 mph were recorded in the Sturgis area. Several power poles and lines were downed in the Spearfish area, with minor damage around Sturgis.
August 18, 2006	Damaging winds associated with a line of thunderstorms moved through Lincoln County and were estimated between 50 and 80 mph. A downburst caused significant damage, especially to crops, which were shredded by wind-blown hail. Source: NWS Sioux Falls
May 23, 2006	Eighty mph straight-line winds damaged a Union County farm. Two outbuildings were destroyed and a third building lost its roof. A fourth building was also damaged, and debris was strewn along a ¼ mile stretch. Tree damage was also documented in the area. Source: NWS Sioux Falls
April 17, 2006	Severe thunderstorms. The earliest reports of large hail and strong winds on record for northwestern South Dakota. Source: NWS Rapid City
June 7-8, 2005	This was one of the most damaging severe thunderstorm events of the past several years for central and northeast South Dakota. In the late afternoon of June 7, a line of thunderstorms developed across western South Dakota and moved east across the state and into west central Minnesota. Widespread damage was reported. Hundreds of grain bins and countless buildings were damaged or destroyed and numerous trees, power lines, and poles were downed. Winds of 60 to over 100 mph were reported. It illustrated the fact that extreme straight-line winds can do as much damage as tornadoes. NWS Aberdeen
March 10, 2005	Sustained winds of 40 to 45 mph with gusts above 60 mph persisted from mid-morning until late afternoon. The winds caused widespread tree damage with branches and smaller tree debris broken off. Several power lines were knocked down by the wind or by windblown debris. This resulted in several power outages, especially between the Missouri and James Rivers. Damages to buildings were mostly to shingles and gutters. However, a metal storage building was blown over

Date	Comments
	at Mitchell. Also at Mitchell, construction barriers were blown over, and windows were broken in two vehicles by blowing rocks. An aluminum recycling cage was blown away at Woonsocket. A window was blown out at a school in Freeman. In Sioux Falls, there was damage to the airport tower.
July 3-4, 2003	A line of severe thunderstorms developed in Montana and moved into and across North Dakota, South Dakota, and Minnesota. It brought large hail and winds over 80 mph at times to Brown, Marshall, and Roberts counties, which resulted in widespread property and crop damage. Approximately 30 percent of Marshall County's 227,000 acres of crops were damaged or destroyed. Trees, branches, and power lines and poles were downed; roofs and siding were damaged from hail and fallen trees; farm outbuildings were damaged or destroyed; and many windows were broken out of homes and vehicles. A crop spraying plane at the Sisseton airport was thrown 450 feet and a 55,000 bushel grain bin in Claire City was blown off of its foundation and flattened. On the opposite side of the state, a supercell thunderstorm developed over Lawrence County and moved into Meade County. It moved through Rapid City with 60 to 70 mph winds and moved quickly east-southeast across southwestern and south central South Dakota producing 60 to 80 mph winds. The strong winds downed many trees and power lines from Rapid City to the Winner area. Source: NCDC, NWS Aberdeen
June 9, 2001	A severe windstorm struck portions of western South Dakota with gusts estimated to 80 mph. The greatest damage occurred in Philip and Wanblee. The damage was consistent with strong straight-line winds. Source: NWS Rapid City
August 1, 2000	A powerful thunderstorm moved into western South Dakota from northeast Wyoming. Winds in the Spearfish area, estimated at 90-110+ mph, were particularly devastating, causing a considerable amount of damage and several injuries. Strong downburst winds were responsible for most of the observed damage. As the storm approached Sturgis, it evolved into a bow echo with winds estimated at 65-80 mph that toppled and blew away merchandise tents that had been set up for the Sturgis Rally. Strong winds in excess of 70 mph were also noted in the Black Hawk, Piedmont, Rapid City, and Ellsworth AFB areas. Source: NWS Rapid City
June 3-4, 2000	Two severe thunderstorms brought strong straight-line winds to Clay and Union counties. The first storm had wind gusts of 70-75 mph. The second storm had 60-65 mph wind gusts. Trees were damaged and a picnic shelter was destroyed Source: NWS Sioux Falls
August 6, 1999	Downburst wind event in Meade County. Winds were estimated up to 70 mph at 8:05 p.m. as the front passed through the area. Numerous trees were damaged and a few were blown down. The worst of the storm hit Ellsworth Air Force Base at 8:18 p.m. where they gusted to 89 mph. Between that time and 8:30 p.m., the wind speed did not drop below 50 mph at the base. Sensors measured gusts of 129 mph and 165 mph. Damage was minimal due the rural location.

Date	Comments
	Source: NWS Rapid City
June 20, 1997	These severe thunderstorms brought strong straight-line winds, estimated at 80-90 mph, which caused widespread tree, crop, power line, and building damage and destruction in Davison County and injured eight people. The damage path was at least 15 miles wide by 50 miles long. Many people believed the damage was caused by a tornado, but the damage assessment proved otherwise. Source: NWS Sioux Falls

Source: NCDC, if not otherwise sourced

Probability

According to the National Climatic Data Center, there were 7,971 wind events (excluding events from associated with snow, see event description above) in South Dakota between 1955 and July 2016 (61 years). Based on this information, the probability that at least one wind event will occur in South Dakota in any given year is 100 percent. Annualized losses are estimated at $2,605,982 , with two injuries per year on average.

Climate Change Considerations

There presently is not enough data or research to quantify the magnitude of potential change that climate change may have on windstorms. Future updates to the mitigation plan should include the latest research on how the windstorm hazard frequency and severity could change. The level of significance of this hazard should be revisited over time.

Hazardous Materials

Description

South Dakota's Codified Law Chapter 33-15 Emergency Management defines a hazardous material as "any material, including but not limited to, explosives, flammable liquids, flammable compressed gas, flammable solids, oxidizing materials, poisons, corrosive materials, and radiological materials, the loss of control or mishandling of which could cause personal injury or death to humans or damage to property or the environment." A hazardous materials incident can occur during production, storage, transportation, use, or disposal of said materials. These substances are most often released as a result of transportation accidents or chemical accidents in plants and can be caused and complicated by a different type of hazard event (e.g., flood, earthquake). They affect humans through inhalation, ingestion, and direct contact with skin. South Dakota is concerned about transportation, fixed facility, and pipeline hazardous materials incidents.

Location

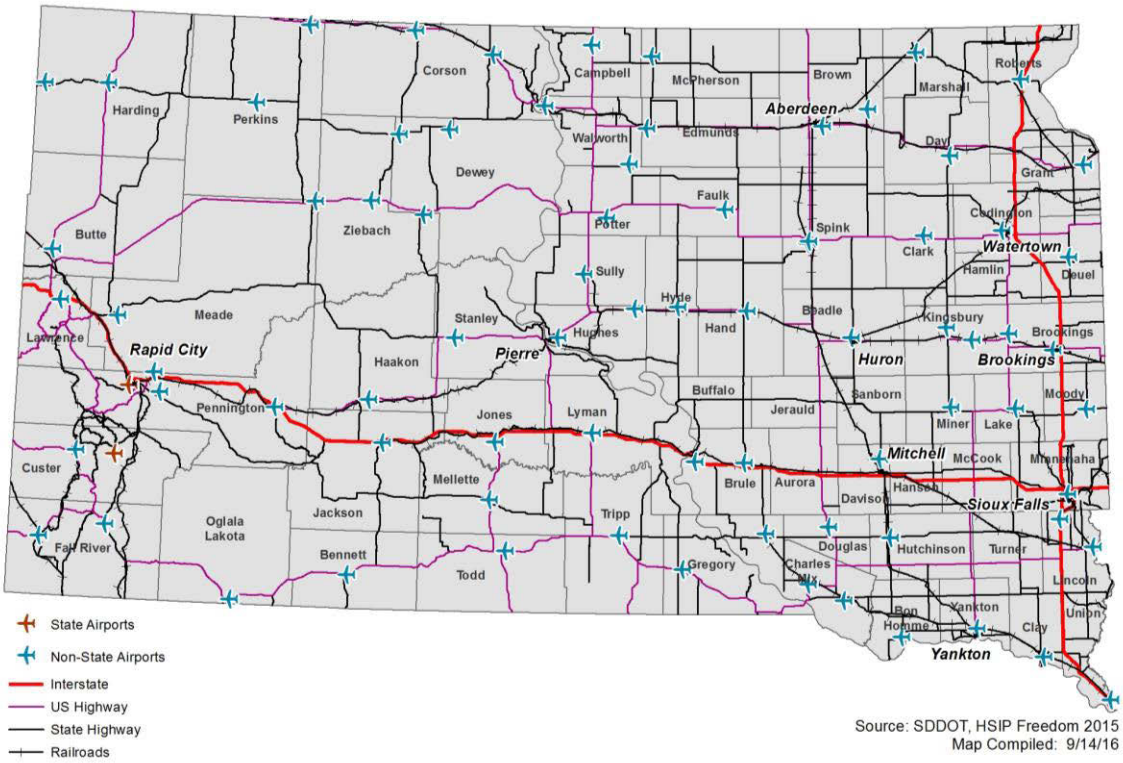
Hazardous materials incidents can happen throughout the state. Localities where hazardous materials are fabricated, processed, and stored as well as those where hazardous waste is treated,

stored, and disposed of are most at risk for hazardous materials incidents. Additionally, localities along transportation corridors that carry these materials to their final destinations are also at risk. More than half of the transportation incidents between 1971 and 2016 occurred in Minnehaha and Pennington counties, where the state's largest cities, Sioux Falls and Rapid City, are located (see the discussion on past events in the following section).

Transportation

Figure 3-33 illustrates South Dakota's transportation infrastructure. There is not a designated hazardous materials route map but the interstates and other highways and railroads are the typical corridors that have hazardous materials being transported on them.

Figure 3-33: South Dakota Transportation Infrastructure



Pipelines

According to the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA), South Dakota's pipeline system is as follows:

- Hazardous liquid line mileage: 803
- Gas transmission line mileage: 1,661
- Gas gathering line mileage: 0
- Gas distribution mileage: 4,570*
- Total pipeline mileage: 7,034

All mileages are for 2011 and are approximate as some data sources may not have contained a complete record of state pipeline mileage.
*Gas distribution service lines (the connection between the distribution line and the end user) are not included in the gas distribution mileage. The total number of such services is 193,628.

Table 3-26: Gas Transmission Line and Hazardous Liquid Line Mileage by County (ranked by percent of total) shows the breakdown of gas transmission line and hazardous liquid line mileage by county. Note that some counties are not listed on the table. Figure 3-34 shows the location of these lines, the majority of which are located in the eastern half of the State.

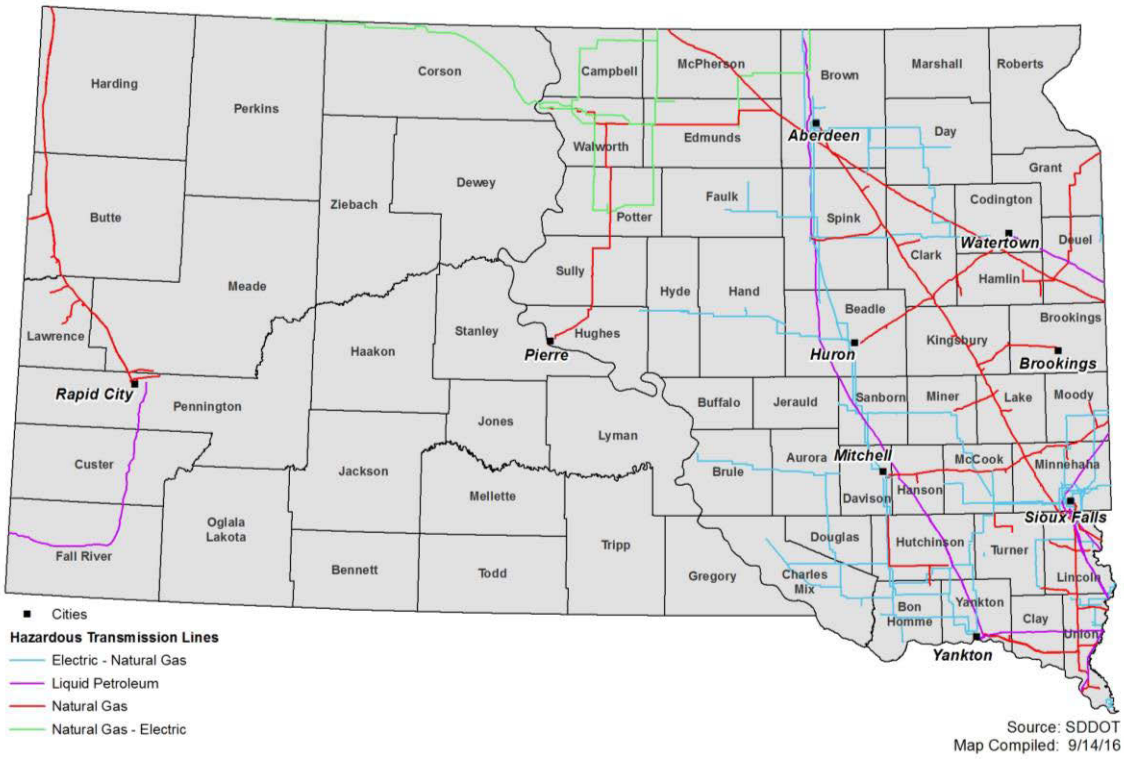
Table 3-26: Gas Transmission Line and Hazardous Liquid Line Mileage by County (ranked by percent of total)

County	Gas Miles	Liquid Miles	Percent of Total
Lincoln	85	106	7.70%
Minnehaha	126	37	6.60%
Brown	83	53	5.50%
Clark	87	39	5.10%
Spink	71	46	4.70%
Butte	99	0	4.00%
Hutchinson	43	52	3.80%
Union	74	19	3.70%
Harding	84	0	3.40%
Kingsbury	67	16	3.30%
Yankton	22	60	3.30%
Deuel	53	24	3.10%
Beadle	19	51	2.80%
Meade	60	0	2.40%
Edmunds	56	0	2.30%
Hanson	20	37	2.30%
Clay	36	17	2.10%
Day	20	33	2.10%
McCook	40	12	2.10%
Walworth	54	0	2.10%
Fall River	0	50	2.00%
Hamlin	50	0	2.00%

County	Gas Miles	Liquid Miles	Percent of Total
Sully	50	0	2.00%
Lawrence	46	0	1.90%
Codington	28	12	1.60%
Lake	39	0	1.60%
McPherson	40	0	1.60%
Pennington	22	18	1.60%
Miner	8	26	1.30%
Grant	30	0	1.20%
Custer	0	29	1.10%
Sanborn	0	29	1.10%
Davison	16	8	1.00%
Marshall	0	26	1.00%
Moody	22	3	1.00%
Potter	26	0	1.00%
Turner	24	0	0.90%
Hughes	19	0	0.70%
Brookings	15	0	0.60%
Roberts	11	0	0.40%
Totals	**1,660**	**803**	**100%**

Source: Pipeline and Hazardous Materials Safety Administration, http://primis.phmsa.dot.gov/comm/reports/safety/SD_detail1.html

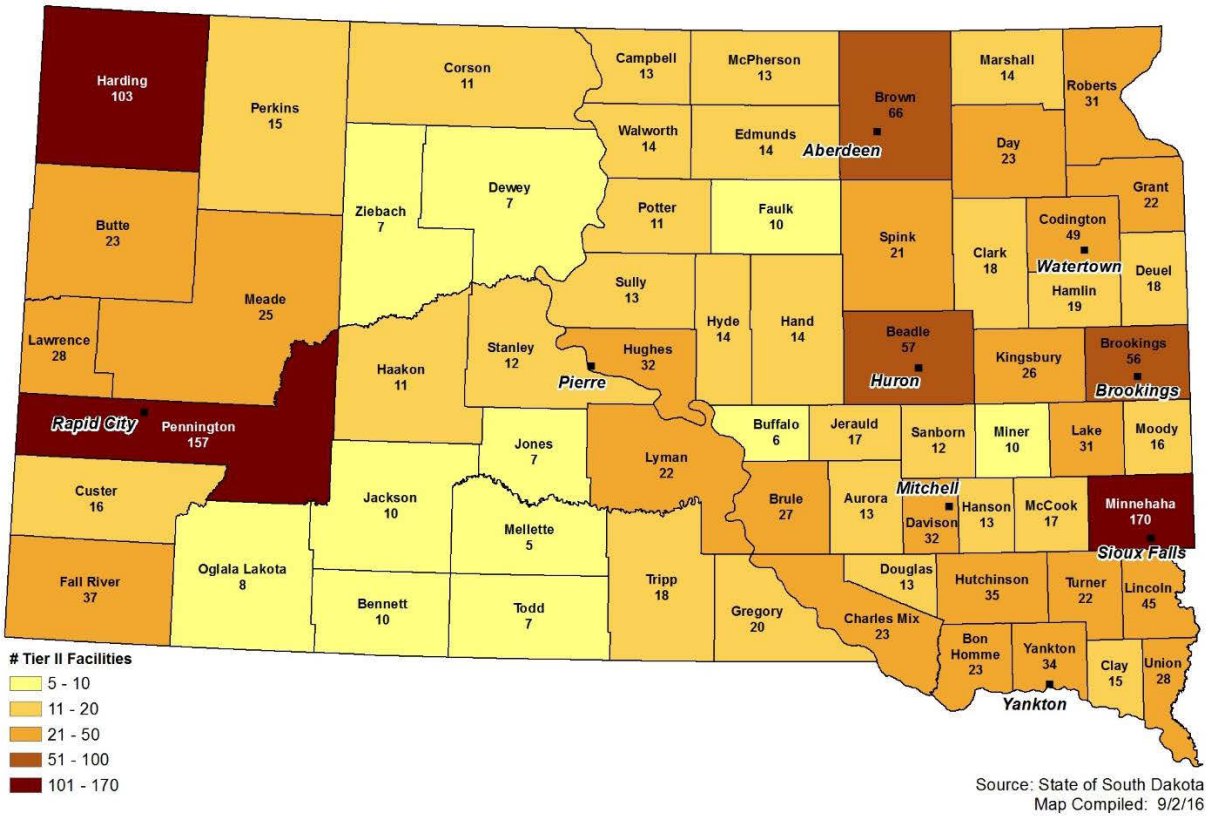
Figure 3-34: South Dakota Hazardous Materials Transmission Lines



Fixed Facility

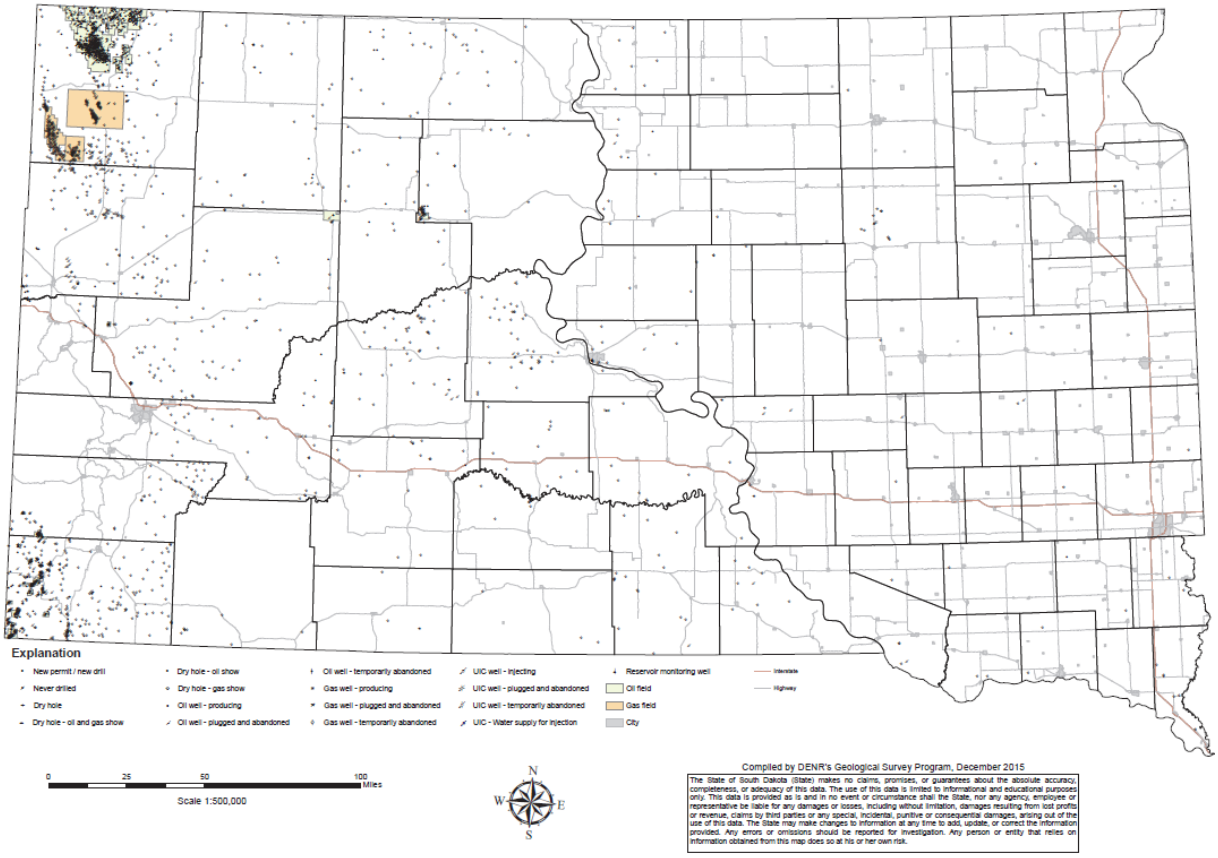
Figure 3-35 shows the number of Tier II facilities in each county. Tier II refers to facilities that are covered by the Emergency Planning and Community Right-to-Know Act (EPCRA). These facilities are required to submit an Emergency and Hazardous Chemical Inventory Form to their LEPC, the State Emergency Response Commission, and local fire departments each year. South Dakota requires that these facilities use the Tier II reporting form.

Figure 3-35: South Dakota Tier II Facility Counts 2015



With the boom in the oil, gas and mining industries seen in the northern great plains, the risk of hazardous materials from mining for resources has increased as new sites are developed. The following figure shows oil and gas resources across the State of South Dakota; these facilities carry inherent risk for hazardous materials spills or accidents related to transportation of oil and gas extraced from these sites. The majority of these sites are west of the Missouri River and in the northwest and southwest corners of the state.

Figure 3-36: South Dakota Oil and Gas, Well, Test Hole and Permit Locations.

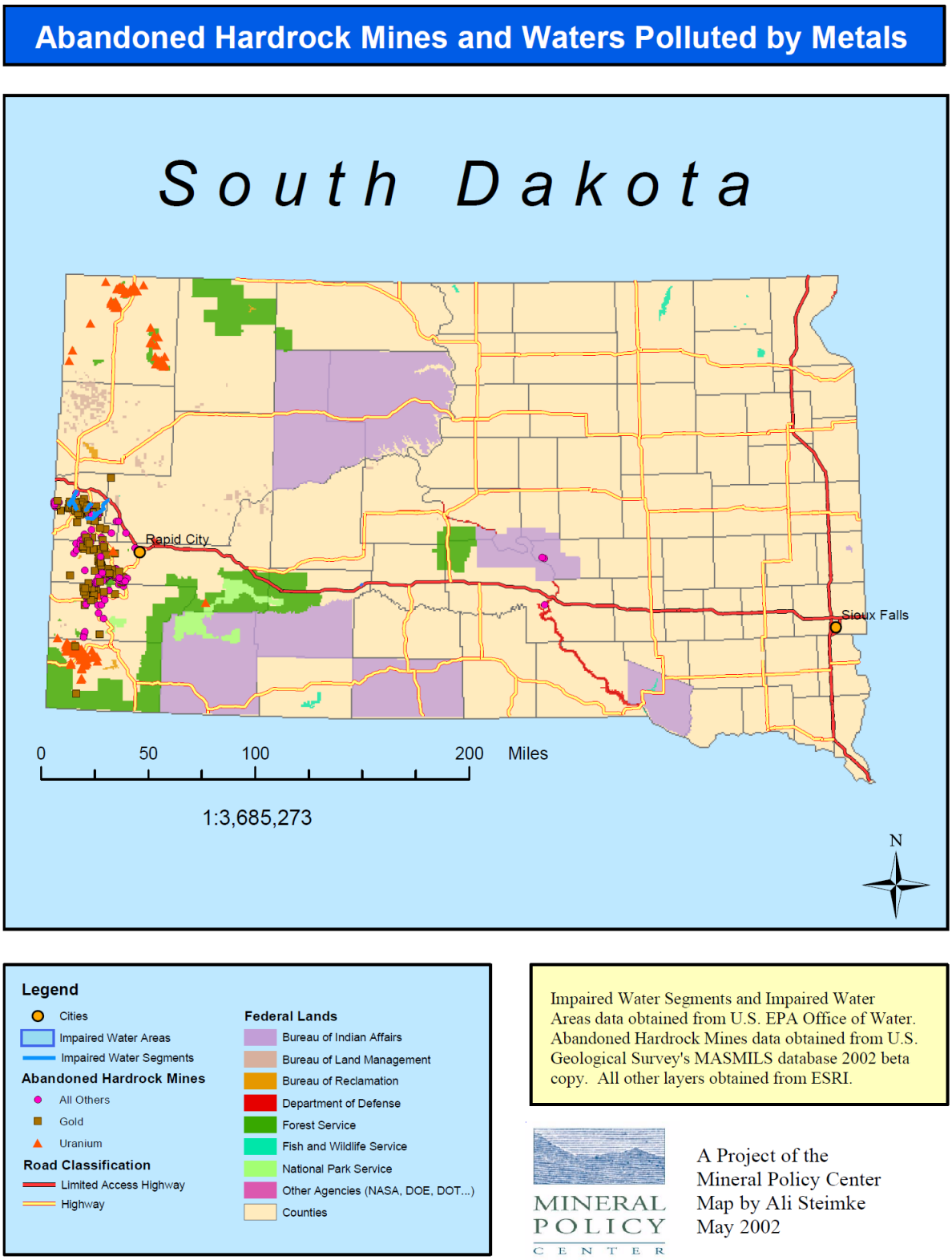


Source: South Dakota DENR – Geological Survey Program

Abandoned mines can sometimes contain hazardous materials and release toxic materials into the surrounding watersheds. The following map shows abandoned mines located in South Dakota.

New mining activity may also pose a concern in the future, such as uranium mining permitting in process in Fall River County (source SHMT 2016). A nuclear waste test project in Spink County was also noted as a potential concern by the SHMT.

Figure 3-37: South Dakota Abandoned Hardrock Mines and Waters Polluted by Metals



Past Events

Transportation

The Hazardous Materials Incident Report Subsystem (HMIRS) of the PHMSA Hazardous Materials Information System was established in 1971 to fulfill the requirements of the federal hazardous materials transportation law. Unintentional releases of hazardous materials or the discharge of any quantity of hazardous waste must be reported. The federal law defines hazardous material as "a substance or material that the Secretary of Transportation has determined is capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and has designated as hazardous materials. The term includes hazardous substances, hazardous wastes, marine pollutants, elevated temperature materials, materials designated as hazardous in the Hazardous Materials Table (see 49 CFR 172.101)."

According to the U.S. Department of Transportation's (DOT) Hazardous Materials Information System, South Dakota experienced 823 transportation incidents involving hazardous materials between 1971 and 2016. The total cost of damage associated with these incidents was $15,033,401. This suggests that South Dakota experiences 18 transportation incidents involving hazardous materials and $334,076 in related damage each year. Among these incidents there were 6 deaths and 33 injuries. The majority of incidents occurred on the highway.

Table 3-27: Transportation Hazardous Materials Incidents, 1971-2016

County	# of Events	Fatalities	Total Injuries	Damages ($)	Evacuations
Minnehaha	434	0	5	536,396	213
Pennington	111	1	2	88,836	0
Brown	34	0	2	286,470	0
Codington	35	0	0	81,146	0
Brookings	18	0	0	207,419	1
Davison	18	0	0	57,948	5
Lawrence	15	0	0	3,366	0
Beadle	14	0	3	10,742	40
Hughes	13	0	0	1,150	0
Meade	12	0	0	84,915	0
Fall River	10	0	0	0	0
Grant	11	0	0	377,456	75
Butte	9	0	1	100	0
Tripp	9	0	0	0	0
Clay	7	0	0	135,500	0
Haakon	7	0	0	575	0
Hand	7	0	0	165,665	0
Custer	6	0	1	0	0
Lake	5	0	0	44,887	0
Oglala Lakota	5	0	0	12,347	0

County	# of Events	Fatalities	Total Injuries	Damages ($)	Evacuations
Yankton	5	0	0	2,500	2
Hutchinson	4	0	0	0	0
Perkins	4	0	0	0	0
Union	4	0	0	134,786	0
Brule	3	0	2	0	0
Potter	3	0	0	133031	0
Walworth	3	0	0	1,200	0
Aurora	2	2	1	4,000,000	0
Corson	2	0	0	1,230	0
Day	3	0	0	0	0
Jackson	2	0	0	83,000	0
Kingsbury	2	0	0	0	0
Lincoln	2	0	0	55,837	21
McCook	2	0	0	0	0
Spink	3	0	0	165,038	0
Ziebach	2	0	0	0	0
Bon Homme	4	0	0	1,622,498	0
Buffalo	1	0	0	100	0
Clark	1	0	0	0	0
Deuel	1	0	0	8,000	0
Edmunds	1	0	0	0	0
Hamlin	1	0	0	26,000	0
Hyde	1	0	0	600	0
Marshall	1	0	0	5,000	0
McPherson	1	0	0	0	0
Moody	1	0	0	89,387	0
Stanley	1	0	0	64,840	0
Sully	1	0	0	8,380	0
Todd	1	0	0	0	0
Turner	1	0	0	0	0
Total	**760***	**3**	**16**	**6,537,056**	**357**

Source: DOT's Office of Hazardous Materials Safety Incident Reports Database, https://hazmatonline.phmsa.dot.gov/IncidentReportsSearch/search.aspx
*Although this column totals up to 761, one event occurred in both Meade and Pennington counties and thus is only counted once.

Reports from PHMSA provide detail and significant incident history for the pipeline systems in the State of South Dakota between 1983 and 2012. Table 3-28 lists these incidents. Similar data was not available during the 2016 update. Significant incidents are those incidents reported by pipeline operators with any of the following conditions met: 1) fatality or injury requiring in-patient hospitalization; 2) $50,000 or more in total costs, measured in 1984 dollars; 3) highly volatile liquid releases of 5 barrels or more or other liquid releases of 50 barrels or more; 4) liquid releases resulting in an unintentional fire or explosion.

Table 3-28: Details of South Dakota Pipeline Incidents, 1983 – 2012

County	Date	Fatalities	Injuries	Damage ($)	Gross Barrels Lost	Barrels Recovered	Type of Incident
Beadle	2/20/2012	0	0	266,340	500	450	Hazardous Liquid
Lawrence	2/10/2012	0	0	108,650	n/a	n/a	Natural Gas Distribution
Clark	5/21/2010	0	0	207,508	0	0	Hazardous Liquid
Hughes	04/02/2009	0	0	150,000	0	0	Natural Gas Transmission
Hughes	02/20/2008	0	0	152,979	0	0	Natural Gas Distribution
Lincoln	03/29/2007	0	0	499,705	0	0	Natural Gas Distribution
Davison	03/08/2007	0	0	505,216	0	0	Natural Gas Transmission
Minnehaha	10/14/2006	0	0	25,100	n/a	n/a	Natural Gas Distribution
Minnehaha	6/16/2006	0	0	14,400	n/a	n/a	Natural Gas Transmission
Sanborn	12/28/2004	0	0	192,102	193	154	Hazardous Liquid
Pennington	10/11/2004	0	0	107,577	n/a	n/a	Natural Gas Distribution
Clark	4/28/2003	0	0	75,027	n/a	n/a	Natural Gas Distribution
Beadle	2/26/2001	0	0	62,642	n/a	n/a	Natural Gas Distribution
Lincoln	10/4/2000	0	0	0	n/a	n/a	Natural Gas Distribution
Custer	8/10/1998	0	0	37,083	123	0	Hazardous Liquid
McCook	5/30/1998	0	0	92,707	n/a	n/a	Natural Gas Distribution
Union	4/4/1998	0	0	49,444	195	0	Hazardous Liquid
Lawrence	3/19/1997	0	0	0	n/a	n/a	Natural Gas Transmission
Pennington	9/12/1994	0	0	68,027	147	30	Hazardous

County	Date	Fatalities	Injuries	Damage ($)	Gross Barrels Lost	Barrels Recovered	Type of Incident
							Liquid
Walworth	10/22/1993	0	1	69,735	n/a	n/a	Natural Gas Distribution
Pennington	4/9/1993	0	0	7,601	300	250	Hazardous Liquid
Pennington	3/2/1993	0	0	174,338	n/a	n/a	Natural Gas Distribution
Minnehaha	1/13/1992	0	0	0	7,200	1,849	Hazardous Liquid
Brown	5/14/1991	0	1	0	n/a	n/a	Natural Gas Distribution
Union	4/8/1991	0	0	184,911	2,881	0	Hazardous Liquid
Codington	2/18/1990	0	0	10,802	332	101	Hazardous Liquid
Minnehaha	12/25/1989	0	0	40,650	1	1	Hazardous Liquid
Minnehaha	12/24/1989	0	0	40,650	6	6	Hazardous Liquid
Yankton	7/5/1989	0	0	0	n/a	n/a	Natural Gas Distribution
McCook	3/21/1989	0	1	0	n/a	n/a	Natural Gas Transmission
Pennington	1/9/1989	0	0	0	0	0	Hazardous Liquid
Pennington	1/9/1988	0	0	0	n/a	n/a	Natural Gas Distribution
Lincoln	12/10/1987	0	0	0	100	0	Hazardous Liquid
Pennington	4/9/1987	0	1	13,321	n/a	n/a	Natural Gas Distribution
Minnehaha	4/8/1987	0	0	444,050	25	0	Hazardous Liquid
Minnehaha	3/11/1987	0	0	888,099	200	5	Hazardous Liquid
Minnehaha	2/16/1987	0	0	7,104,796	715	19	Hazardous Liquid
Brown	9/25/1986	2	0	551,471	n/a	n/a	Natural Gas Distribution
Pennington	12/20/1985	0	0	93,633	n/a	n/a	Natural Gas Distribution
Kingsbury	6/17/1985	0	0	0	n/a	n/a	Natural Gas

County	Date	Fatalities	Injuries	Damage ($)	Gross Barrels Lost	Barrels Recovered	Type of Incident
							Transmission
Decatur	5/7/1984	0	0	6,796	n/a	n/a	Natural Gas Distribution
Beadle	2/13/1983	0	0	n/a	n/a	n/a	Natural Gas Transmission

Source: DOT's PHMSA Significant Incident Listings and Incident Report Files, http://primis.phmsa.dot.gov/comm/reports/safety/IncDetSt_st_SD_flt_sig.html?nocache=9577
Notes:
The costs in the years prior to 2012 are in 2012 dollars.
For years 2002 and later, property damage is estimated as the sum of all public and private costs reported in the 30-day incident report. For years prior to 2002, accident report forms did not include a breakdown of public and private costs, so property damage for these years is the reported total property damage field in the report.

Fixed Facility

The U.S. Environmental Protection Agency maintains a database on toxic chemical releases and other waste management activities, which are reported annually by certain covered industry groups as well as federal facilities: the Toxics Release Inventory. In 2014, the most recent data available, 6.2 million pounds of hazardous materials were disposed of or released in South Dakota. Table 3-29 ranks chemical releases by county for 2014 Table 3-30 and Table 3-31 show the top 10 releasing facilities and the top 10 chemicals released in 2014.

Table 3-29: Chemical Releases* by County, 2014 (all figures are in pounds)

County	Total On-site Disposal or Other Releases	Total Off-site Disposal or Other Releases	Total On- and Off-site Disposal or Other Releases
Minnehaha	2,940,292	17,834	2,958,128
Lawrence	1,383,945		1,383,945
Grant	602,028	238,523	840,551
Brookings	504,877	3,587	508,514
Pennington	114,582	16	114,599
Codington	67,742	1,470	69,229
Roberts	59,856		59,856
Lincoln	53,168		53,168
Brown	41,378	126	41,504
Turner	38,051		38,051
Edmunds	31,532		31,532
Lake	23,029	770	23,799
Yankton	21,203	1,477	22,940
Spink	18,456		18,456
Day	12,861	0	12,861
Beadle	8,379		8,379
Davison	6,362	317	6,684

County	Total On-site Disposal or Other Releases	Total Off-site Disposal or Other Releases	Total On- and Off-site Disposal or Other Releases
Bon Homme	5,850		5,850
Campbell		**1,936**	**3,872**
Hamlin	887		887
Deuel	0	389	389
Hutchinson	7	0	7
Total	**5,934,483**	**266,445**	**6,203,200**

Source: U.S. Environmental Protection Agency, Toxics Release Inventory Explorer, www.epa.gov/triexplorer/
*Includes releases to land, air, and water

Table 3-30: Top 10 South Dakota Facilities with Greatest Total Releases,* 204 (all figures are in pounds)

Facility	County or Parish or County Equivalent	Total On-site Disposal or Other Releases	Total Off-site Disposal or Other Releases	Total On- and Off-site Disposal or Other Releases
John Morrell & Co.	Minnehaha	2,759,044	16,682	2,775,726
Wharf Resources	Lawrence	1,365,327	0	1,365,327
Otter Tail Corp (DBA Otter Tail Power Co)	Grant	484,478	209,726	694,206
South Dakota Soybean Processors LLC	Brookings	413,013	0	413,013
Starmark Cabinetry	Minnehaha	73,727	0	73,727
U.S. DOD USAF	Pennington	52,791	14	52,805
Pete Lien & Sons Inc.	Pennington	48,202	0	48,202
Valley Queen Cheese Factory Inc.	Grant	39,300	750	40,050
Woodland Cabinetry Inc.	Roberts	38,176	0	38,176
Glacial Lakes Energy LLC	Codington	37,840	0	37,840

Source: U.S. Environmental Protection Agency, Toxic Resources Inventory, www.epa.gov/tri/
*Includes releases to land, air, and water

Table 3-31: Top 10 Chemicals Reported Released* in South Dakota, 2014 (all figures are in pounds)

Chemical	Total On-site Disposal or Other Releases	Total Off-site Disposal or Other Releases	Total On- and Off-site Disposal or Other Releases
Nitrate Compounds	2,991,027.00	11,362.00	3,002,389.00
Lead Compounds	1,064,981.10	3,987.37	1,068,968.47
Barium Compounds	431,494.00	209,726.00	641,220.00
N-Hexane	456,874.56	.	456,874.56

Chemical	Total On-site Disposal or Other Releases	Total Off-site Disposal or Other Releases	Total On- and Off-site Disposal or Other Releases
Xylene (Mixed Isomers)	168,483.59	9	168,492.59
Acetaldehyde	132,017.26	.	132,017.26
Hydrochloric Acid (1995 and after Acid Aerosols only)	101,402.00	.	101,402.00
Chromium	81,333.27	816.56	82,149.83
Ammonia	70,936.00	6,334.00	77,270.00
N-Butyl Alcohol	61,508.09	.	61,508.09

Source: U.S. Environmental Protection Agency, Toxic Resources Inventory, www.epa.gov/tri/; *Includes releases to land, air, and water

Probability

Transportation

According to the U.S. Department of Transportation's Hazardous Materials Information System, there were 831 transportation incidents involving hazardous materials in South Dakota between 1971 and 2016 (45 years). Based on this information, the probability that at least one transportation incident involving hazardous materials will occur in South Dakota annually is 100%.

Pipeline

According to the U.S. Department of Transportation's Office of Pipeline Safety, there were 42 pipeline incidents in South Dakota between 1983 and 2012 (29 years). Based on this information, the probability that at least one pipeline incident will occur in South Dakota annually is 100%.

Fixed Facility

According to the U.S. Environmental Protection Agency's Toxic Resource Inventory, 6.1 million pounds of hazardous materials were disposed of or released in South Dakota in 2014. Based on this information, there is a 100 percent probability that a fixed facility will dispose of or release a hazardous material in South Dakota each year.

Geologic Hazards

A multitude of geologic hazards affect the State of South Dakota. For purposes of this plan, the geologic hazards profiled consists of landslides, mudflows, expansive soils, subsidence, and earthquakes

Description

What Is a Landslide?

Landslides are a serious geologic hazard common to almost every state in the United States. It is estimated that nationally they cause up to $2 billion in damage and 25 to 50 deaths annually. Globally, landslides cause billions of dollars in damage and thousands of deaths and injuries each year.

Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly. Gravity is the force driving landslide movement. Factors that allow the force of gravity to overcome the resistance of earth material to landslide movement include saturation by water, steepening of slopes by erosion or construction, alternate freezing or thawing, earthquake shaking, and volcanic eruptions.

Landslides are typically associated with periods of heavy rainfall or rapid snow melt and tend to worsen the effects of flooding that often accompanies these events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides.

Landslides are defined as a rapid slipping of a mass of earth or rock from a higher elevation to a lower level under the influence of gravity and water lubrication. More specifically, rockslides are the rapid downhill movement of large masses of rock with little or no hydraulic flow, similar to an avalanche. Water-saturated soil or clay on a slope may slide downhill over a period of several hours. Earthflows of this type are usually not serious threats to life because of their slow movement, yet they can cause blockage of roads and do extensive damage to property.

Earthquakes also may cause landslides by shaking unconsolidated or weathered material from slopes. Rockslides triggered by an earthquake in Montana in 1959 caused an entire mountainside to slide into the Madison River Gorge, killing 27 people in its path, damming the gorge, and forming a new lake. Humans have triggered a number of tragic landslides that have caused great damage and loss of life. In the Los Angeles area of California, extensive real estate development carried out on hillsides has resulted in widespread mudflows after winter rains have saturated the over-steepened embankments of soil. In some areas, slow-moving earthflows have been initiated by the lubrication of certain types of underlying clays by septic tank effluent. Submarine slides, or a sliding mix of seawater and mud, are called turbidity currents. Undersea landslides can travel several hundred miles across very gradual slopes, riding on a thin film of water that reduces friction.

What Is a Mudflow?

Mudflows (or debris flows) are rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt, changing the earth into a flowing river of mud or “slurry.” A slurry can flow rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. A slurry can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way. In hilly or mountainous areas for years after a wildfire, heavy rainfall creates mudflow and landslide risks to people, structures, and infrastructure located below such areas.

Damages from mudflows are covered under the National Flood Insurance Program; landslides are not.

What is Expansive Soil?

Expansive soils are referred to by many names. "Expandable soils," "expansive clays," "shrink-swell soils," and 'heavable soils" are some of the many names used for these materials. Expansive soils contain minerals such as smectite clays that are capable of absorbing water. When expansive soils are present, they will generally not cause a problem if their water content remains constant. The situation where greatest damage occurs is when there are significant or repeated moisture content changes. When they absorb water they increase in volume. The more water they absorb the more their volume increases. Expansions of ten percent or more are not uncommon. This change in volume can exert enough force on a building or other structure to cause damage. The force of expansion is capable of exerting pressures of 15,000 pounds per square foot or greater on foundations, slabs, and other confining structures. Cracked foundations, floors and basement walls are typical types of damage done by swelling soils. Damage to the upper floors of the building can occur when motion in the structure is significant. Expansive soils will also shrink when they dry out. This shrinkage can remove support from buildings or other structures and result in damaging subsidence. Fissures in the soil can also develop. These fissures can facilitate the deep penetration of water when moist conditions or runoff occurs. This produces a cycle of shrinkage and swelling that places repetitive stress on structures.

Expansive soils are present throughout the world and are found in each American state. Every year they cause billions of dollars in damage. The American Society of Civil Engineers estimates that 1/4 of all homes in the United States have some damage caused by expansive soils. In a typical year in the United States they cause a greater financial loss to property owners than earthquakes, floods, hurricanes and tornadoes combined. Even though expansive soils cause enormous amounts of damage most people have never heard of them. This is because their damage is done slowly and cannot be attributed to a specific event. The damage done by expansive soils is then attributed to poor construction practices or a misconception that all buildings experience this type of damage as they age.

What is Subsidence?

Land subsidence is the sinking of the land over manmade or natural underground voids. Subsidence occurs naturally and also through man-driven or technologically exacerbated circumstances. Natural causes of subsidence occur when water in the ground dissolves minerals and other materials in the earth, creating pockets or voids. When the void can no longer support the weight of the earth above it, it collapses, causing a sinkhole depression in the landscape. Often, natural subsidence is associated with limestone erosion, but may also occur with other water-soluble minerals. Man-driven or technology-exacerbated subsidence conditions are associated with the lowering of water tables, extraction of natural gas, or subsurface mining activities. As the underground voids caused by these activities settle or collapse, subsidence occurs on the surface.

Location

Landslides

Areas that are generally prone to landslide hazards include existing old landslides, the bases of steep slopes, the bases of drainage channels, and developed hillsides where leach-field septic systems are used. Areas that are typically considered safe from landslides include areas that have not moved in the past, relatively flat-lying areas away from sudden changes in slope, and areas at the top or along ridges, set back from the tops of slopes.

In certain areas of South Dakota landslides do occur. Over the years, many landslides have been dealt with by the State of South Dakota and in particular the South Dakota Department of Transportation (SDDOT). SDDOT has spent a lot of time stabilizing landslides throughout the state. Two of the larger slides were the US 12 Missouri River Crossing at Mobridge and the US 212 Missouri River crossing at Forest City. At Mobridge, stone columns were used for the first time in the United States to stabilize a clay-shale landslide. Forest City also used stone columns and also incorporated the use of massive concrete shear pins installed by slurry wall process to stabilize the approach berm. This was the first time in the United States that this technique was used to mitigate a landslide of this magnitude. A civil engineer, who was head of the SDDOT Geotechnical Activity Section from 1969 to 2001, achieved national recognition for his innovative work with these two landslides. A slide area also exists near Cheyenne Crossing along U.S. Highway 14A in Lawrence County. Road crews were engaged in landslide repair efforts at the site in 2012 and continuing into 2013. A potential landslide area existed near Yates Pond in Lawrence County along U.S. Highway 14A, but SDDOT mitigated this area in 2010.

Subsidence

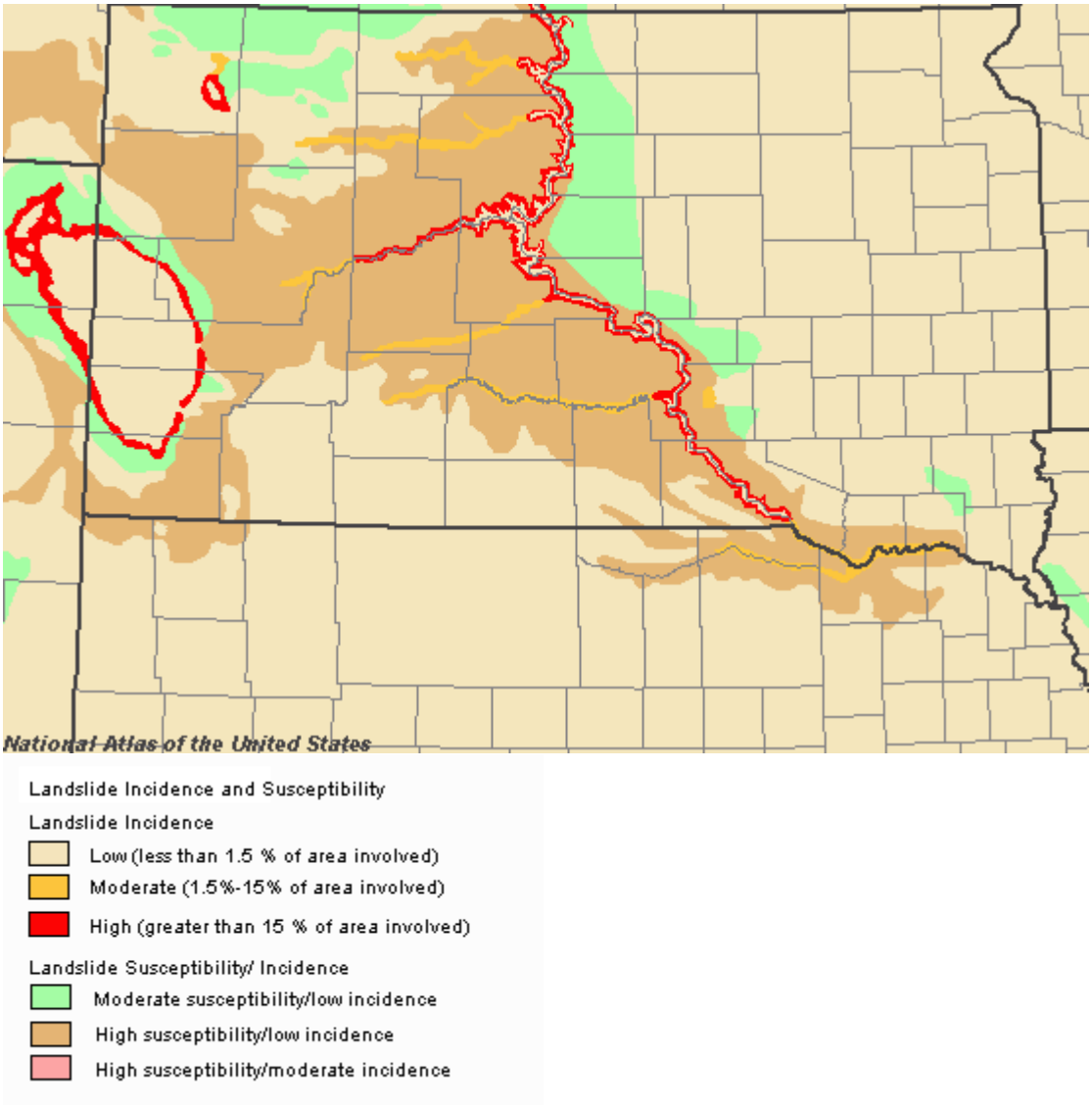
There are certain areas in South Dakota at risk to subsidence (see Figure 3-38). The Niobrara Formation (Upper Cretaceous) and its equivalents are the most widespread carbonate rocks in western Kansas, eastern Nebraska, and southeastern South Dakota. The Niobrara is generally covered by more than 50 ft. (15 m) of younger sediments. Small fissures, less than 1,000 ft. (300 m) long and up to 100 ft. (30 m) deep, are present, but they are not common and are generally irregularly spaced with 1,000 ft. (300 m) or more of solid rock between fissures.

In western South Dakota and adjacent parts of Wyoming and Montana, Paleozoic and Cretaceous carbonate rocks, arched steeply upwards, encircle the structural dome that forms the Black Hills. Caves and open fissures are common in the Paleozoic carbonate rocks. A few caves contain many miles of passages but most of the cave passages and fissures in the Black Hills area only extend up to 3,000 ft. (900 m) in length and are generally less than 150 ft. (45 m) in depth. Closely spaced solution joints also are prevalent.

Expansive Soils

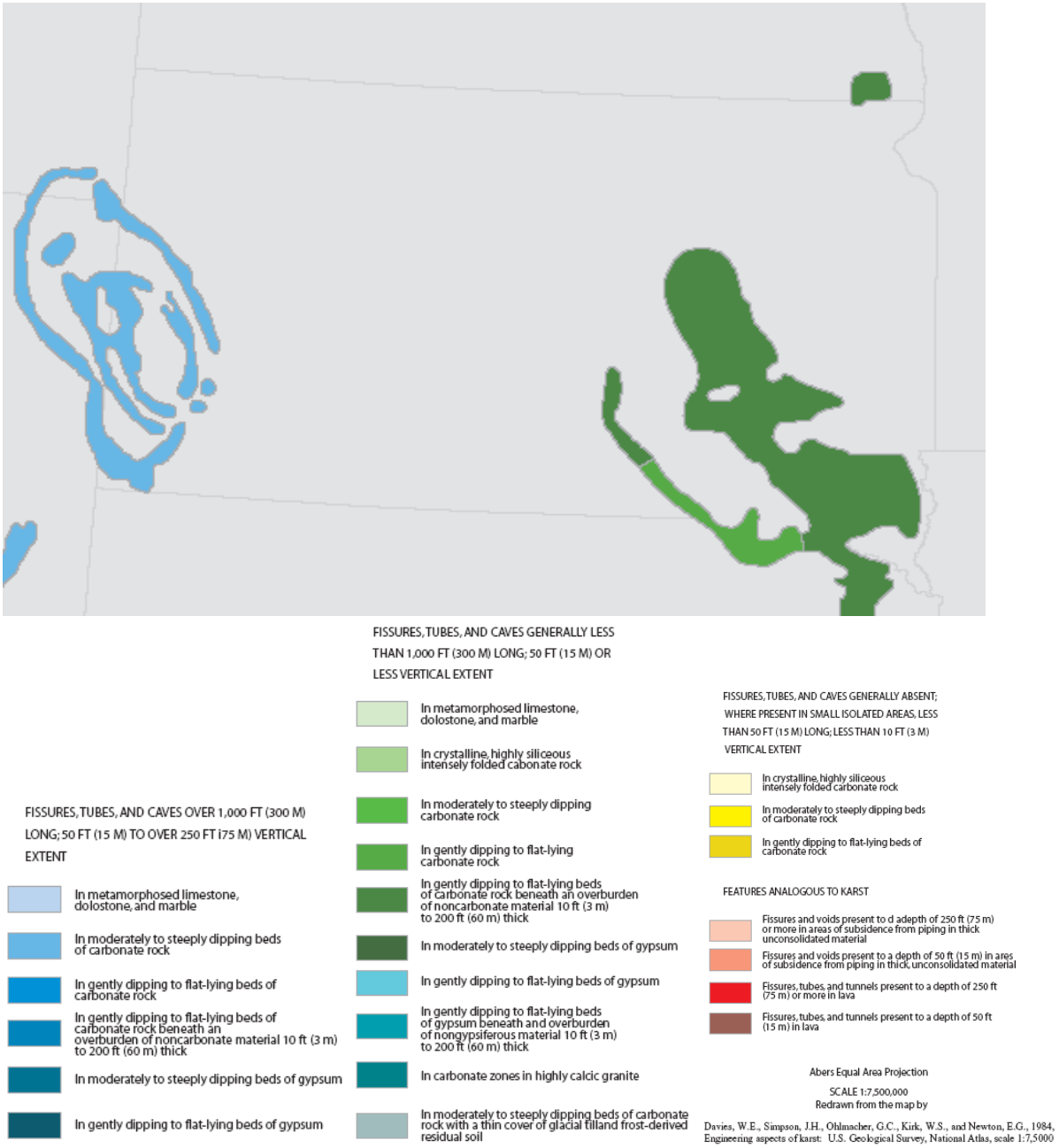
There are certain areas of South Dakota at risk to expansive soils. The map below shows the geographic distribution of soils which are known to have expandable clay minerals which can cause damage to foundations and structures. It also includes soils that have a clay mineral composition which can potentially cause damage. The map is meant to show general trends in the geographic distribution of expansive soils. It is not meant to be used as a property evaluation tool. It is useful for learning areas where expansive soils underlie a significant portion of the land and where expansive soils might be a localized problem. According to this map, the majority of the State has the potential for expansive soils.

Figure 3-38: South Dakota Landslide Incidence and Susceptibility



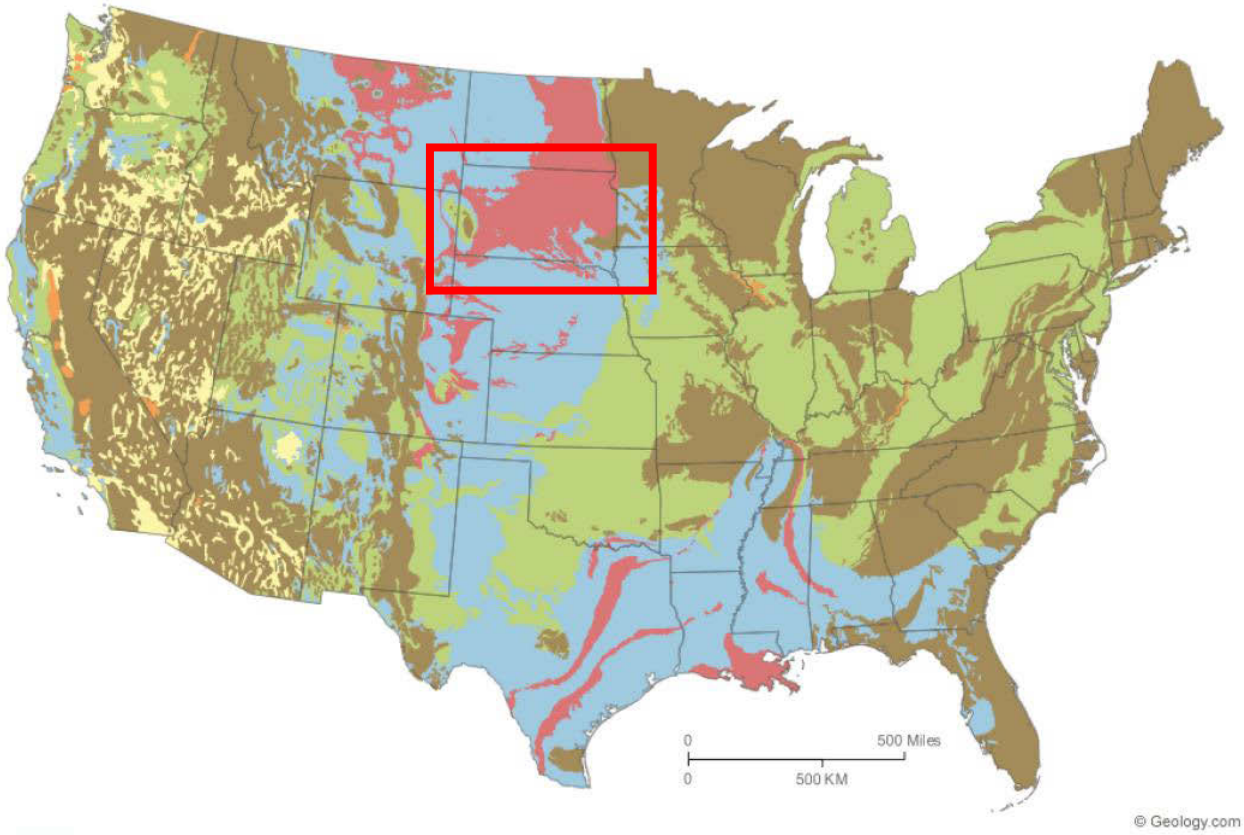
Source: U.S. Geological Survey, map generated by www.nationalatlas.gov

Figure 3-39: State of South Dakota Subsidence Risk



Source: The National Karst Map http://www.nckri.org/map/maps/engineering_aspects/davies_map_PDF.pdf

Figure 3-40: South Dakota Expansive Soils



Over 50 percent of these areas are underlain by soils with abundant clays of high swelling potential.

Less than 50 percent of these areas are underlain by soils with clays of high swelling potential.

Over 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.

Less than 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.

These areas are underlain by soils with little to no clays with swelling potential.

Data insufficient to indicate the clay content or the swelling potential of soils.

Source: The map above is based upon "Swelling Clays Map of the Conterminous United States" by W. Olive, A. Chleborad, C. Frahme, J. Shlocker, R. Schneider and R. Schuster. It was published in 1989 as Map I-1940 in the USGS Miscellaneous Investigations Series. Land areas were assigned to map soil categories based upon the type of bedrock that exists beneath them as shown on a geologic map. In most areas, where soils are produced "in situ", this method of assignment was reasonable. However, some areas are underlain by soils which have been transported by wind, water or ice. The map soil categories would not apply for these locations.

Past Events

Table 3-32 provides information regarding past landslides, mudflows, subsidence, and expansive soils.

Table 3-32: South Dakota Landslides and Mudflows

Date	Comments
2012-2013	Road crews worked to repair a slide area near Cheyenne Crossing along U.S. Highway 14A in Lawrence County. Repair efforts included excavating landslide debris and constructing a new back slope.
2006	A landslide near Wasta in Pennington County took the water system out for a week.
August 8, 2004	A heavy rain at the rate of about one inch per hour fell over the area burned by the Grizzly Gulch fire in Lawrence County just six weeks before. The result was that the steep hillsides lost most of their topsoil, which flowed down into Deadwood. Hardest hit was the area of the Northern Hills General Hospital where a retaining wall was damaged, Whistler's Gulch Campground and Mile High Mobile Home Park, and properties along Sherman Street in Deadwood. Cleanup would have been well over one million dollars, but the use of a state prison work crew and volunteers reduced the out of pocket expense to property owners.
2001	A mudflow caused by heavy rain occurred after the Black Hills Grizzly Gulch Fire in 2001. The mudflow caused damage to many homes in the burn area or below.
June 1976	**Flash Flooding, Mudslides (FEMA-511-DR)** In a 24-hour period on June 13-14, 3 to 10 inches of rain fell in the northern Black Hills. And additional two to three inches of rain plus heavy snow was recorded over this area on the June 15 and 16. The run-off from this precipitation did considerable damage in the counties of Lawrence, Meade, Butte, and Harding. There was also a problem with mudslides and landslides.
May 1952	Sturgis/Deadwood—Heavy rains brought flash flooding that tore up streets and gas pipelines in Sturgis. Bridges were washed out and water erosion caused rock slides. Water damage and landslides also occurred in Deadwood.

Limited information was available regarding past impacts from swelling soils. Modern building practices often take this hazard into account and incorporate mitigation. The Department of Transportation does normal maintenance and accounts for this hazard in their construction practices, which does result in additional costs for mitigation and road maintenance. Research yielded little information regarding past impacts from subsidence.

Probability

Although historical landslide/mudflow/subsidence/expansive soil occurrence data is limited it can be assumed that landslides will occur occasionally in the future, typically during wet climate cycles or following heavy rains, but in limited areas of the state.

Earthquake Description

Earthquakes east of the Rocky Mountains are less frequent than in the western United States and are typically felt over a much broader region. Most of North America east of the Rocky Mountains has infrequent earthquakes. Most of the enormous region from the Rockies to the Atlantic can go years

without an earthquake large enough to be felt, and several U.S. states have never reported a damaging earthquake. The earthquakes that do occur are typically small and occur at irregular intervals.

East of the Rockies it is difficult to determine the specific fault that is responsible for an earthquake since this vast region is far from plate boundaries, which are in the Atlantic Ocean, the Caribbean Sea, and in California and offshore from Washington and Oregon. Known faults do exist in this "stable continental region," but numerous smaller or deeply buried faults remain undetected, even most of the known faults are poorly located at depths typically associated with earthquakes. Thus, few earthquakes east of the Rockies can be linked to named faults. Also, it is difficult to determine if a fault is still active and capable of generating an earthquake. Consequently, in most areas east of the Rockies, the best guide to earthquake hazards is the earthquakes themselves.

South Dakota is somewhat more seismically active than other areas in the Northern Great Plains, although the earthquake magnitudes have been relatively minor to date. At least two mechanisms may be important in generation of the earthquakes. These include initiation of movement along preexisting fractures due to crustal plate movements or movements due to glacial rebound. Ground motion accelerations can be calculated based upon historical seismic records, but the poor quality of the database does not allow great confidence to be placed in those calculations. These calculations show highs in ground motion acceleration that correspond reasonably closely with areas of greater earthquake frequency.

Location

A zone of higher earthquake frequency extends from the northeastern corner of the state and a generally higher frequency of earthquakes is recorded along the eastern flank of the Black Hills and in the southwestern corner of the state. The earthquakes occurring in South Dakota appear to be concentrated along the Great Lakes Tectonic Zone and possibly along the boundaries of the structural provinces in the Precambrian, crystalline basement.

The Black Hills, being a structural dome, is full of faults and joints dating to the uplift some 50 million years ago. Very little strain now accumulates along them, so only small, rare earthquakes have occurred in the region during historic times. Work by several geologists during the last decade or so have shown that much of the region has widely spaced joints and faults breaking the Earth's crust into blocks, each a township size in area. Fortunately, there is very little strain to release as earthquakes in South Dakota. In the south central part of the state, the South Dakota Geologic Survey have mapped some of these blocks and have identified individual block-bounding faults that have moved 40 feet or more vertically and a few hundreds of feet horizontally in very small increments during the last 50 million years.

Past Events

According to the USGS, no major earthquakes have been reported in South Dakota since 1967. However, earthquakes have historically caused relatively minor damage in South Dakota. Documented damages include cattle stampedes, shaking buildings, falling or rattling dishes and pictures, stuck doors and windows, cracked window glass, foundations heaving or cracking, wall and ceiling plaster cracks, furniture moving, etc.

The following is excerpted directly from an abridged version of Carl A. von Hake's "South Dakota History" in Earthquake Information Bulletin, Volume 9, Number 1, January-February 1977:

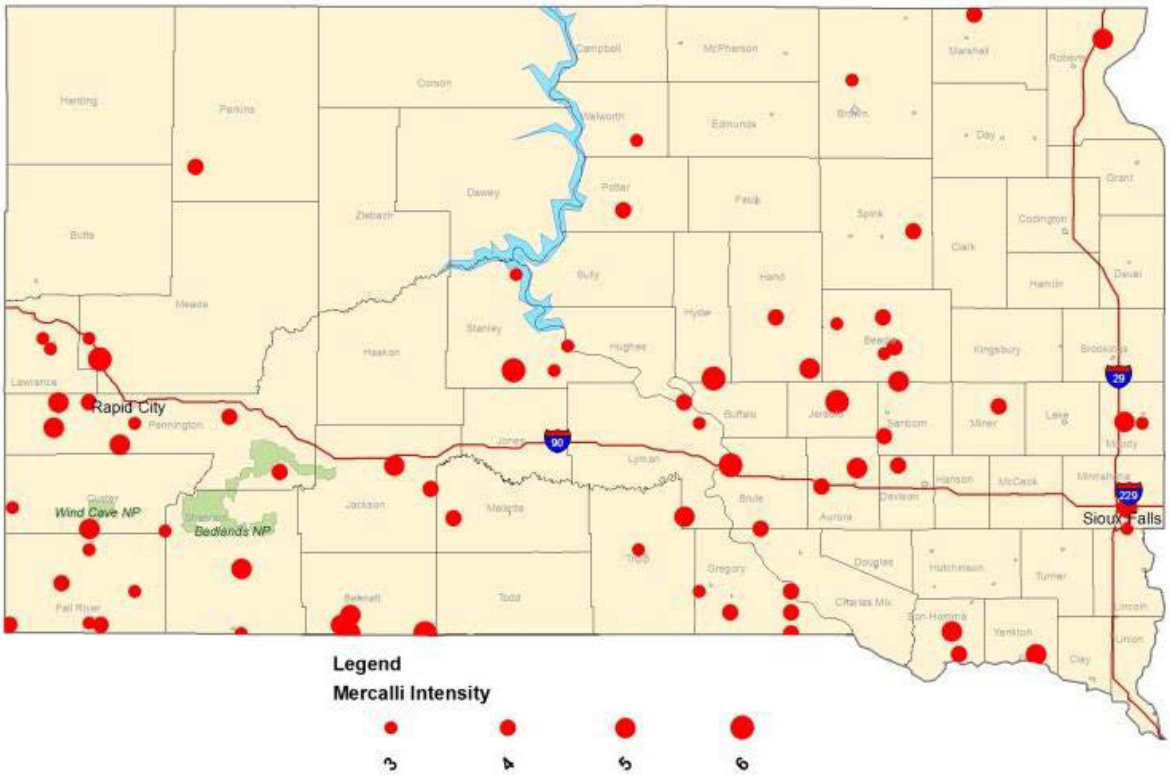
> The first earthquake reported in the region occurred on October 9, 1872, 17 years before South Dakota was admitted to the Union. This shock was apparently centered near Sioux City, Iowa. Severe effects were noted at Sioux City, at Yankton and White Swan, South Dakota, and elsewhere in the Dakota Territory. Two strong tremors 45 minutes apart caused some damage in eastern Nebraska on November 15, 1877. The large felt area (over 350,000 square kilometers) included all or most of South Dakota.
>
> On December 29, 1879, a mild earthquake produced rumbling noises at Yankton (V). Two shocks, estimated at intensity IV-V, occurred in the Black Hills region on October 11, 1895. The first was reported strongest at Rochford; the latter was strongest at Keystone and Hill City.
>
> The earthquake of June 2, 1911, was reported from Huron (V) and other places in South Dakota, Iowa, and Nebraska, an area covering approximately 100,000 square kilometers. It was apparently centered in the James River valley. A shock on October 23, 1915, near Kadoka, was accompanied by loud noises. Some cracks in the ground were reported (V). The Black Hills region experienced another earthquake on November 16, 1928. At Custer and Rochford there was a deep rumbling sound (V).
>
> Buildings were jarred, dishes rattled, and loose object swayed (V) at Sioux Falls from an October 11, 1938, tremor. Police stations received more than 50 calls from alarmed residents. The total felt area affected was about 7,500 square kilometers in South Dakota and one town in Minnesota. A strong, localized shock on July 23, 1946, caused several cracks in water mains (VI) at Wessington. The earthquake, which occurred about 12:45 a.m., also awakened sleepers at Huron. The small felt area extended from Pierre to De Smet and from Wessington to Redfield. A similar disturbance occurred on December 31, 1961, causing slight damage at Pierre. Reports of cracked plaster and a cracked cement floor were received. Also, buildings shook and loose objects rattled. Newspaper and police switchboards were swamped with calls from alarmed residents (VI). Fisherman along the Missouri River reported that many fish leaped into the air at the time the earthquake occurred. The felt area extended from Midland on the west to Huron on the east.
>
> An earthquake with an abrupt onset and a short duration (3-5 seconds) was felt by all at Wind Cave National Park. The March 24, 1964, tremor caused small rocks to fall in the cave. Buildings creaked, and a slight trembling motion was noticed at Hot Springs (V). Three days later (March 27), another shock was reported from the same area. The epicenter was apparently located near Van Tassell, Wyoming, although no instrumental records were available for this event owing to the proximity in time of its occurrence to the occurrence of the great Alaska earthquake. There was no connection between the shocks, although many persons within the felt area thought effects from the Alaskan earthquake had been observed. Maximum intensity (V) was noted at Van Tassell; felt reports were received from Harrison and Hyannis, Nebraska, and Edgemont, Hot Springs, Keystone, Pine Ridge, and Provo, South Dakota.

The strongest tremor in this series (measured at magnitude 5.1) occurred at 3:08 a.m. CST, March 28, 1964. The instrumental epicenter was near Merriman, Nebraska, where broken goods were reported in stores; also, dishes were broken in homes, and stucco under windows cracked. Sixteen kilometers south, 75 cracks were noted in the highway, and some steep banks tumbled along the river (VII). Plaster fell at Rushville, and part of a chimney toppled at Alliance, Nebraska. Slight damage also occurred in southwestern South Dakota - a retaining wall was damaged at Deadwood, there were a few slight cracks in ceiling plaster at Interior, a glass container broke in a market at Martin, and wall and ceiling plaster cracked at Pine Ridge. Several farms near Martin also reported broken glass. The total felt area, including several places in Wyoming, covered approximately 230,000 square kilometers. One town in Montana (Alzada) reported this tremor.

An earthquake on June 26, 1966, near Rapid City, caused slight damage over a small area. A patio and concrete steps were cracked at Rapid City; well water was muddied and could not be used for several hours at Keystone (VI). The magnitude 4.1 shock produced intensity V effects at Deadwood and Silver City. It was also felt at Black Hawk, Hill City, Lead, Piedmont, Pine Ridge, and Oglala Lakota County (previously Shannon County).

A magnitude 4.4 shock on November 23, 1967, was felt over a small area of southern South Dakota and northern Nebraska. Press reports indicated that houses shook and dishes fell from shelves in the Winner - Rosebud - White River areas (V). Many residents were frightened at Gregory, where furniture was shifted and some windows were cracked. Livestock stampeded through fences on some farms. Felt reports were also received from Carter, Chamberlain, Colome, Martin, Mission, and Stephan, South Dakota, and Ainsworth and Dunning Nebraska. One isolated report stated the shock was felt by a few people at Douglas, Wyoming.

Figure 3-41 Earthquakes in South Dakota 1872-2016



Source: South Dakota Geological Survey

Table 3-33: South Dakota Earthquakes

Date	Comments
February 7, 2014	Magnitude 3.0, Northwest of Platte
December 12, 2013	Magnitude 3.5, South of Colonial Pine Hills
January 16, 2012	Magnitude 3.0 near Custer/Fall River/ Oglala Lakota County (previously Shannon County) borders
November 15, 2011	Magnitude 3.3 in Fall River County
November 14, 2011	Magnitude 4.0 in Fall River County
August 9, 2011	Magnitude 3.4 near Hughes/Stanley County border
September 25, 2009	Magnitude 3.8 at 10:11 am. 30 miles northwest of Belle Fourche
February 7, 2007	Maximum Intensity III—Magnitude 3.1, 4:35 a.m. 7 miles west southwest of Wasta, 17 miles west northwest of Wall.
October 19, 2005	Magnitude 3.1
January 24, 2004	Magnitude 2.5
January 5, 2004	Magnitude 2.8
November 21, 2003	Magnitude 3.5
May 25, 2003	Intensity IV at Kyle and Gordon, III at Pine Ridge and Chadron—Magnitude 4.0, 1:32 a.m. 35 miles east of Pine Ridge, 115 miles southwest of Pierre.
July 26, 2002	Magnitude 3.1
July 12, 1998	Magnitude 3.1

Date	Comments
May 3, 1996	Magnitude 3.1
February 6, 1996	Intensity V—9:10 a.m. 24 miles south southwest of Yankton (Magnitude 3.6). Felt by many people. The quake caused Gavins Point Dam personnel to conduct dam safety checks. Intensity V—9:08 a.m. Northwest of Mt. Rushmore (3.7 Richter). Felt by many people who noticed typical earthquake ground movement. Both of these quakes were centered about 5 km below the surface. Neither quake can be definitely associated with any mapped fault, but both are near known or postulated faults.
July 3, 1995	Intensity III—Southwest of Ft. Thompson (2.8 Richter)
March 18, 1994	Intensity III—Hot Springs (2.8 Richter)
September 5, 1993	Intensity III—Deadwood (2.7 Richter)
October 25, 1990	Intensity V—Aurora County north of Plankinton and west southwest of Storla.
March 2, 1990	Intensity IV— Oglala Lakota County (previously Shannon County) north of Manderson.
January 28, 1990	Intensity V— Oglala Lakota County (previously Shannon County) north of Manderson.
November 26, 1989	Intensity III—Walworth County near Lowery.
October 15, 1987	Intensity III—Beadle County northeast of Wessington.
July 9, 1987	Intensity III—Beadle County near Virgil.
May 25, 1986	Intensity IV—Sanborn County slightly northeast of Storla.
March 4, 1983	Intensity VI—On Hyde–Buffalo County border south of Mac's Corner.
November 15, 1982	Intensity V—Bon Homme County near Avon.
July 11, 1982	Intensity V—Moody County near Egan.
September 13, 1981	Intensity V—Bennett County southeast of Batesland on the Nebraska border.
May 16, 1975	Intensity IV—Fall River County near Edgemont.
October 19, 1971	Intensity IV—3:15 p.m. Jackson County half way between Kadoka and Norris. Glass rattled.
November 23, 1967	Intensity V—Lyman County east of Hamill near Tripp-Lyman County border. Magnitude 4.4, felt in Winner, Rosebud, White River areas. Many residents were frightened in Gregory, where furniture shifted and windows cracked. Livestock stampeded through fences on some farms.
Jun 26, 1966	Intensity VI—5:59 a.m. Meade County between Bethlehem and Tilford. Magnitude 4.1, slight damage at Rapid City. At Keystone, well water was muddied for several hours. At Rapid City, concrete steps cracked away from a house and a patio cracked. At Deadwood, there was a fallen tree due to the shock. At Keystone, one observer reported he could see the ground moving. Pictures on walls bounced, buildings creaked, and dishes rattled. There was a gradual on-set with a bumping swaying motion. In Rapid City, buildings creaked and loose objects rattled. There was a rapid on-set with a bumping motion, and moderately loud earth sounds were also heard.
August 26, 1964	Intensity IV—Pennington County south of Wall in Badlands National Park.
March 28, 1964	Intensity VII—Epicenter in western Nebraska. Magnitude 5.1. Duration: 10 seconds. Depth: 65.98 miles. (This quake was not actually in South Dakota but caused damage anyway. It is listed here to represent the danger from earthquakes that originate outside the state's borders.)

Date	Comments
March 27, 1964	Unknown strength due to proximity of the Great Alaska Quake—9:00 p.m. Near Van Taussell, Wyoming. Felt throughout Black Hills with an apparent intensity of IV. (This quake was not actually in South Dakota but caused damage anyway. It is listed here to represent the danger from earthquakes that originate outside the state's borders.)
March 24, 1964	Intensity V—12:12 a.m. Custer County north northeast of Hot Springs near Fall River-Custer County border. Felt by all at Wind Cave National Park. Small rocks fell in cave, buildings creaked, and loose objects rattled. Moderately loud, rumbling noise heard. Abrupt on-set, trembling motion. Duration: 3–5 seconds.
December 31, 1961	Intensity VI—10:35 a.m. Stanley County near Wendte. Felt by many in Pierre. Slight damage. Plaster cracked, cement floors cracked, refrigerator doors shaken open, clothes dryer moved several inches. Fishermen along the Missouri River reported that the moment the quake struck, hundreds of fish jumped into the air. Buildings shook and loose objects rattled. Intensity V—Murdo—felt by many. Plaster on walls cracked, venetian blinds swayed, dishes rattled, faint earth sounds heard, trembling motion with abrupt onset. Intensity IV—Presho and Winner. Intensity I-III—Draper, Hayes, Huron, Midland, Onida, Philip, and White River.
January 12, 1959	Intensity IV—7:15 a.m. Spink County near Doland. Felt by many; rumbling sound followed by what sounded like a boiler explosion. Dishes and windows rattled.
December 3, 1957	Intensity IV—1:30 a.m. Davison County near Loomis. Awakened several people in Mount Vernon, where buildings creaked and loose objects rattled. At Mitchell, houses shook and windows and doors rattled. Livestock was "alarmed and all bunched up."
December 31, 1953	Intensity IV—Gregory County south of Burke.
December 21, 1953	Intensity IV—Perkins County near Zeona
November 14, 1952	Intensity IV—Pennington County near Silver City
December 14, 1949	Intensity III—Gregory County near Dallas.
Jun 3, 1949	Intensity IV—Potter County near Gettysburg.
March7, 1949	Intensity III—Hand County near Miller.
August 25, 1947	Intensity IV—Gregory County near Bonesteel.
July 23, 1946	Intensity VI—Jerauld County near Wessington Springs. In Wessington water mains cracked at two points.
November 10, 1945	Intensity IV—3:00 a.m. Bon Homme County east of Kingsbury and southeast of Tyndall. Rattled dishes.
May 16, 1943	Intensity IV—12:40 p.m. Custer County north northeast of Hot Springs near Fall River-Custer County border. Felt by many "like heavy trucks rumbling down the street." Dishes rattled.
March 11, 1942	Intensity III—11:55 a.m. Meade County near Sturgis. Light shock felt in Deadwood, Fort Meade, Lead, Piedmont, Sturgis, Terraville, Trojan, Whitewood, and Black Hawk.

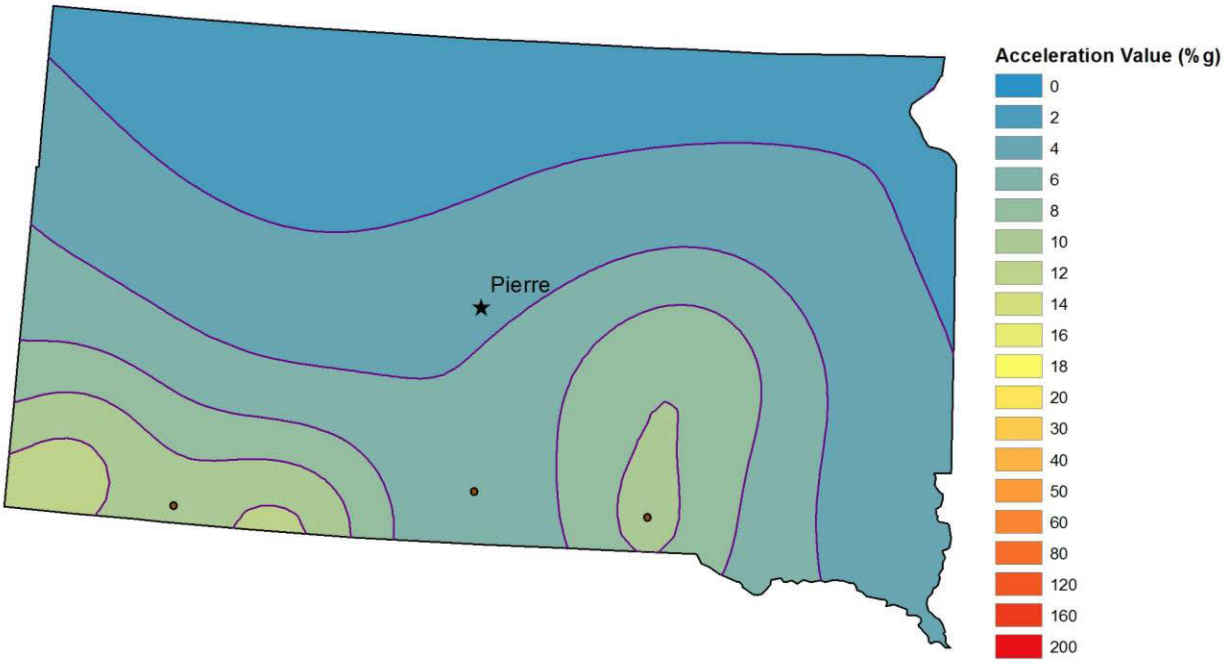
Date	Comments
May 25, 1941	Intensity V—12:25 a.m. Custer County north northeast of Hot Springs near Fall River-Custer County border. In Hot Springs, one wall reported cracked. Pictures and light fixtures swayed in Hot Springs, Rapid City, and Martin. Not felt in Longvalley, Belvidere, Oelrichs, or Cottonwood.
Jun 10, 1939	Intensity IV—12:30 p.m. Gregory County on Nebraska border south of Fairfax. There was one shock of about 15 seconds duration. It was of a gradual bumping nature, direction northwest to southeast, with a rumbling sound.
November 4, 1938	Intensity IV—10:10 and 10:15 p.m. Gregory County near Whetstone Bay. Felt in Academy, Lake Andes, Burke, Colome, Dallas, Gregory, and Platte.
October 11, 1938	Intensity V—3:37 a.m. Minnehaha County between Renner and Sioux Falls. In Sioux Falls, buildings jarred, beds shook, dishes rattled, and pictures and other loose objects swayed. A rumbling subterranean noise came as a climax of the earthquake. The recording pens on water and electric meters at the municipal water works were jarred. Sioux Falls police received more than 50 calls from citizens. Intensity IV—Humboldt, Madison, Parker, Spencer, and Yankton. Intensity III and under—Canton, Centerville, Egan, Hudson, Lennox, Salem, Sherman, and Vermillion. Not felt in Beresford, Brookings, Howard, Mitchell, or Olivet.
October 1, 1938	Intensity V—4:15 p.m. Brule County near Chamberlain.
January 2, 1938	Intensity IV—11:05 a.m. Beadle County near Broadland.
October 30, 1936	Intensity IV—Custer County north northeast of Hot Springs near Fall River. Not felt elsewhere.
November 1, 1935	Intensity III—Moody County between Egan and the Minnesota border on Highway 34.
August 30, 1934	Intensity IV—On the Brule and Charles Mix County border between Bijou Hills and Academy: Abrupt trembling motion accompanied by a rumbling sound, felt by many, small objects moved. Also felt in Pukwana.
January 29, 1934	Intensity IV—6:30 a.m. Marshall County north northwest of Kidder near Newark. Awakened several, dishes rattled, rumbling sound.
January 17, 1931	Intensity IV—Aurora County east of Platte Lake and south of White Lake. Felt by many. Trembling motion with loud sounds.
October 6, 1929	Strong Shock—6:30 a.m. City of Yankton. Deep rumbling resembling distant thunder set windows rattling. Some dishes thrown from shelves. Felt around Yankton and at Gayville and Volin about 15 miles to the east.
November 16, 1928	Intensity V—Pennington County near Mystic City. Felt at Custer and Rochford.
December 30, 1924	Intensity IV— 10:10, 10:15, 10:20, and 10:30 p.m.—Custer County north northeast of Hot Springs near Fall River-Custer County border.
January 2, 1922	Intensity VI—Brule County near Chamberlain.
September 24, 1921	Intensity IV—Aurora County east of Platte Lake and south of White Lake.
March 16, 1921	Intensity III—Minnehaha County near Sioux Falls at Lincoln County border.
July 14, 1920	Intensity III—Fall River County near Oelrichs.
June 29, 1916	Intensity III—Tripp County near Winner.
February 24, 1916	Intensity III— Oglala Lakota County (previously Shannon County) -near Pine Ridge.

Date	Comments
October 23, 1915	Intensity V—Jackson County near Kadoka. Loud noises and some cracks in the ground.
Jun 2, 1911	Intensity V—Beadle County near James River crossing into Sanborn County. Felt in the James River Valley.
May 10, 1906	Intensity VI—Bennett County near southeast corner and on the Nebraska border. Felt from Rushville to Valentine, Nebraska.
March 14, 1900	Intensity III—5:00a.m. Brown County near northeast corner of Richmond Lake. Intensity III—3:00a.m. Brown County near northeast corner of Richmond Lake.
December 6, 1899	Intensity IV—Hand County near Miller.
October 12, 1895	Intensity V—Pennington County near Hayward.
October 11, 1895	Intensity IV–V—Pennington County near Hayward. Felt at Rochford, Keystone, and Hill City.
December 29, 1879	Intensity V—Yankton County near Yankton.
August 17, 1876	Intensity IV—Lyman County near Lower Brule.
October 9, 1872	Intensity V—At Sioux City, Iowa. Severe effects at Yankton and White Swan. Felt in all or most of South Dakota.
February 9, 1872	Intensity III—Stanley County near Mission Ridge.

Probability

South Dakota is relatively geologically stable based upon the sparse data available. However, there is potential for larger earthquakes than the magnitude 4.4 earthquake that struck the Black Hills in 1964. The U.S. Geological Survey estimates this risk as only a 10 percent chance of exceeding a 5.1 magnitude in any one 50-year period. The map in Figure 3-42 shows ground motions that have a 2 percent chance of being equaled or exceeded in a 50-year period.

Figure 3-42: Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years



Source: U.S. Geological Survey, National Earthquake Information Center

3.3 Assessing Vulnerability and Estimating Potential Losses by Jurisdiction

44 CFR Part 201 Requirement:

[The State risk assessment shall include an] overview and analysis of the State's vulnerability to the hazards described in paragraph (c)(2), based on estimates provided in local risk assessments. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards and most vulnerable to damage and loss associated with hazard events….

Plan must be reviewed and revised to reflect changes in development….

44 CFR Part 201 Requirement:

[The State risk assessment shall include an] overview and analysis of potential losses to identified vulnerable structures, based on estimates provided in local risk assessments….

The following section assesses the vulnerability of South Dakota by county to the hazards previously identified and profiled. For purposes of this plan, county boundaries are the smallest jurisdictions considered and include information pertinent to all smaller jurisdictions located within the county. Other geographical, political and jurisdictional boundaries such as cities, towns, municipalities, and townships are better evaluated in specific hazard mitigation plans, which allow for the collection and analysis of more detailed information at the specific jurisdictional level.

Vulnerability is defined as the extent to which people and property are exposed to harm or damages created by a hazard. The quantification of vulnerability is based on best available data on the hazard and exposed populations and buildings. The method of determining vulnerability varies by hazard and data availability, and these methods are discussed in detail in each hazard profile. Where the data permits, loss estimations to people and property are provided. It was noted at stakeholder meetings during the 2007 plan update that the state may want to consider impacts to South Dakota's agricultural economy as a vulnerability factor in future plan updates. As such, the hazard profile "Agricultural Diseases and Pestilence" was added during the 2009 update. Additional data on crop and livestock loss due to natural hazards was added to the 2013 plan update. For the 2016 HIRA update, the hazard profile and vulnerability analysis for Summer Storms was added. Also added in 2016 was a consequence analysis for each hazard. The consequence analysis considers the impact on the hazards on the public; responders; continuity of operations including continued delivery of services; property, facilities, and, infrastructure; the environment; the economic condition of the state and public confidence in the state's governance.

The 2007 update to this plan synthesized and analyzed data that was previously included in several attachments and annexes. In 2009, the plan expanded on those data resources and attempted to fill previous data gaps. In 2013, additional data was obtained to fill in data gaps identified in the 2010 plan. This new data utilized the methods established in 2010 and 2007 and allowed for a comparative perspective on vulnerability to the hazards which impact the state. The results of this analysis are presented in this section. In addition, and in response to the FEMA evaluation of 2007, the growth and development trends were developed further in this update. The social vulnerability section, which was added in 2007, was also re-evaluated in the 2009 update and again in the 2013 update. Counties and other

local jurisdictions can follow this same process to assist in developing or updating their local mitigation plans in a manner that consistently reflects vulnerability evaluations.

New vulnerability assessment methodologies were conducted during the 2007 update to refine vulnerability and loss estimates for flood, tornadoes, severe wind, winter storm, wildfire, and earthquake. These assessments were updated in 2009-2010, 2013-2014, and again in 2016. A significant change to the 2009-2010 plan was the incorporation of a statewide flood loss estimation based on FEMA's HAZUS-MH computer model. Additional information was added in 2009-2010 and 2016 to improve the drought vulnerability section. A limited vulnerability analysis was added for hazardous materials. Vulnerability and loss assessments were not conducted for geologic hazards due to their ranking as limited for planning significance. New vulnerability assessment methodologies and data were introduced in 2013 and continued in 2016. Data on crop loss and livestock death was added to the profiles and vulnerability assessments for agricultural pests and disease, drought, and winter storm. Vulnerability assessments for tornado, wind, and winter storm were enhanced with more detailed analysis on events with higher magnitudes (e.g. tornadoes of F1 or greater), damages, and casualties. The 2016 vulnerability assessments also used new classification schemes to refine the vulnerability ranking system. Damage estimates were inflated to 2016 dollars. Vulnerability for the Rural Electric Cooperatives was further analyzed with new data on hazards and completed or planned mitigation projects. The 2016 update also includes new data on Individual Assistance and Public Assistance claims for major disasters that have occurred in South Dakota. With each successive update the vulnerability and loss estimates improve, though some information gaps remain.

Each update process includes a review of current and approved local hazard mitigation plans covering 66 counties and 3 tribal plans for vulnerability and loss information. While some plans used a standard format for identifying potential loss, most of the plans contained limited vulnerability information and utilized different methodologies for determining the vulnerability. Therefore, it is currently not possible to consolidate the vulnerability and loss information from the local plans for a complete statewide comparison.

Growth and Development

As part of the plan update process, the state looked at changes in growth and development at the county level and examined these changes in the context of the state's hazard-prone areas and how the changes in growth and development affect loss estimates and vulnerability. Increases in population growth and development can result in greater exposure to hazards, particularly atmospheric hazards such as tornadoes windstorms, and winter storms.

General Land Use in South Dakota

Land use and development trends exert a significant impact on the vulnerability assessments for South Dakota relative to specific hazards. In some cases, a dominant land use may increase the vulnerability to a specific hazard, such as agricultural diseases or wildfire. Land use trends may also indicate areas where vulnerability and risk may be more sustained than in other areas of the state, and also help identify areas where vulnerability and risk levels vary. This is particularly important to examine in a statewide hazard mitigation plan, to ensure the document reflects accurate variability of these elements.

One characteristic of local land use in South Dakota that must be considered in both state and local hazard mitigation planning is how the land use patterns are changing at the community level. Identifying both the type and rate of change from existing land uses to future land uses, whether they are planned or unplanned, can help to identify the local jurisdictions most subject to development pressures and consequently help to focus the mitigation planning to minimize the vulnerability to future disasters of the newly constructed neighborhoods, facilities, and infrastructure. Data from local plans can be used to identify the jurisdictions where planned land uses are significantly different from existing land uses.

Land cover in South Dakota is predominantly cropland and rangeland. The significant forested areas in the state are concentrated in the Black Hills region, located in the south west corner of the state. Large bands of cultivated cropland and pastureland or haymaking areas run from north to south across eastern South Dakota. Areas in the western half of the state are marked with cropland and pastureland and pockets of barren land, but are primarily characterized by grasslands. Highly concentrated areas of development, including residential and commercial/industrial/transportation classifications of land, are limited geographically and centralized around the major population centers of Rapid City, Pierre, and Sioux Falls. Other areas of concentrated urbanization include Aberdeen, Watertown, and Huron, which correspond to the population and demographic information outlined in the next section.

County Land Use in South Dakota

Notable and important growth and development trends were identified in the review of county hazard mitigation plans. Considerations of county growth and development trends is important in that increased growth exposes more citizens and building to hazards such as tornadoes, winter storms, wildfires, and floods. As such, Table 3-34 summarizes the trends identified in the local and tribal hazard mitigation plans.

Table 3-34 Growth and Development Trends Extracted from Local Plans

County	Growth and Development Trend
Aurora	No development is expected to increase the severity of hazards identified in the plan.
Beadle	The only community in Beadle County that is experiencing any growth and/or development is Huron. The rest of the jurisdictions have experienced declining populations over the past 10 years. Due to the declining population, these jurisdictions do not maintain plans for growth or development.
Bennett	It took into consideration present and projected land use and development trends within the communities and the unincorporated portions of Bennett County. The planning team evaluated county and community demographic data to get a picture of the changes that have taken place during the past 60 years.
Bon Homme	Little development is expected anywhere in the county. The population is expected to continue decreasing. However, one place where growth was identified to likely occur is the southern edge of Tyndall, which is covered in part by a flood prone area identified by HAZUS. The conversion of wetlands and other marginal land in the county to agricultural land due to the ethanol boom is of some concern because it may increase the

County	Growth and Development Trend
	probability and severity of flooding as the land's natural capacity to absorb excess surface water is decreased. This development could also have a negative impact on rural roads and structures. Conditions for growth were also identified along the Missouri River. Since this area is fairly rugged with a considerable amount of cedar trees and brushy vegetation, new housing constructed in this area would be somewhat vulnerable to wildfire.
Brookings	There was a 12 percent population increase 1990 and 2000. Mitigation activities are needed at the business level to ensure the safety and welfare of workers and limit damage to industrial infrastructure. Transportation systems in Brookings County have expanded and evolved
Brule	No development in this county is expected to increase severity of identified hazards.
Buffalo	No development in this county is expected to increase severity of identified hazards.
Charles Mix	There is no significant development occurring in Charles Mix, nor is any activity foreseen. However, the conversion of wetlands and other marginal land in the county could have an adverse impact on flooding. Much of the county's soil is fertile and suitable for growing crops, such as corn and wheat. Cattle production is also important. The economy is dependent upon agriculture. The County experienced a population decline during the last half of the twentieth century, but did register a slight increase from 1990 to 2000. The City of Wagner has decided to participate in NFIP to ensure that future development does not occur in the City's flood zone. Some development has been occurring in the hilly terrain west of Wagner. It is possible that area will experience increased damage from fires because the hilly terrain and thick vegetation makes firefighting difficult.
Codington	Construction of new homes
Custer	Rural areas of Custer County and the communities of Custer and Hermosa will grow over the next 20 years (in-migration of elderly persons looking for retirement and development of urban fringe areas).
Day	Steadily losing population since 1930. No future buildings, infrastructure, or critical facilities proposed that would be located in identified hazard areas. Mitigation options will be considered in future land use decisions.
Douglas	No development in this county is expected to increase severity of identified hazards.
Edmunds	No future development is identified to be within hazard areas.
Gregory	No development in this county is expected to increase severity of identified hazards.
Haakon	Declining number of farms, rural population steadily decreased and now leveling off, and some rural subdivision development. No future development is identified in a hazard area.
Hamlin	Slow and steady growth due to its proximity to larger communities such as Watertown and Codington County. No future buildings, infrastructure, or critical facilities are planned within hazard areas and mitigation options

County	Growth and Development Trend
	will be considered in future land use decisions. Small businesses and industries that are agricultural related are also increasing employment in the area. Agriculture is the basis of the economy.
Hand	In 2006, the County had a population of 3,323, a decline of 11.2% from the 2000 Census, which translates to around 2.3 persons per square mile, classifying the County as mostly rural. One major city, Miller, has a population of 1,530. The population has been decreasing over the years. The declining population offers limited potential for growth in the county and communities. As a result, there are currently no planned or potential buildings.
Hughes	Population increase, reduction in household size, trend toward rural living without farming, size of farms increasing, no future development was identified in a hazard area.
Hutchinson	No development in this county is expected to increase severity of identified hazards.
Hyde	Declining population. Small, rural county. Future development will be within or near the city. No future development is identified within hazard areas.
Jerauld	No development in this county is expected to increase severity of identified hazards.
Jones	Declining number of farms, rural population steadily decreased and now leveling off, and some rural subdivision development. No future development is identified in a hazard area. Future development will focus on the traveling public.
Lincoln	Reduction in farmland, replaced by housing.
McCook	Since 1930, the population of McCook County has experienced a rise and then a decline of population growth. This trend is expected to continue.
Meade	Growth and development along I-90, Sturgis, and also in the southwest corner of the County near Piedmont and Summerset. The Black Hills Motorcycle Rally increases population and chances for hazards for a short period during the Rally in August of each year.
Mellette	Residential growth is not expected to be significant but needs to be controlled through planning and development guidelines. No development is expected to increase the severity of identified hazards.
Moody	Steadily losing population since 1930. Agriculture is the basis of the economy. No future buildings, infrastructure, or critical facilities are planned to be located in hazard areas. Mitigation options will be considered in future land use decisions.
Oglala Lakota	The county Hazard Mitigation Plan indicates that there is minimal population growth.
Pennington	Population growth, most in established towns and communities, mining is

County	Growth and Development Trend
	focus of industrial land use; however, residential development southwest of Rapid City in the county is greatly increasing the risk and exposure to catastrophic wildland fire.
Potter	Steadily losing population since 1930. Agriculture is the basis of the economy. No future buildings, infrastructure, or critical facilities proposed to be located in identified hazard areas. Mitigation options will be considered in future land use decisions.
Roberts	Steadily losing population since 1930. Agriculture is the basis of the economy. No future buildings, infrastructure, or critical facilities proposed to be located in identified hazard areas. Mitigation options will be considered in future land use decisions.
Spink	Decreasing population and limited potential for growth. There are no planned or potential buildings.
Stanley	Population increase, reduction in household size, trend toward rural living without farming, size of farms increasing, no future development is identified in a hazard area.
Sully	Declining number of farms, rural population steadily decreased and now leveling off, and some rural subdivision development, but the overall population trend is decidedly downward. Development is occurring along the bluffs overlooking the Oahe Reservoir.
Tripp	No development in this county is expected to increase severity of identified hazards.
Turner	Steady decline in population since 1930, increase shown in 2000 census.
Union	Steady decline in population since 1930, large increase in population since 1990.
Yankton	Intensively farmed. Many of the poorly drained areas have been left as wetlands. There is no significant development in areas that are prone to flooding. In general, increased population in and around the City of Yankton leads to increased risk to the hazards identified in the plan.
Rosebud Sioux Tribe	Rural housing may increase vulnerability to winter storms and tornadoes. Increasing number of methamphetamine labs.
Sisseton-Wahpeton Oyate Tribe	The Districts within the Oyate are experiencing growth and have comprehensive land use plans which identified future areas for development. Specifically, available undeveloped areas projected for residential, commercial, and industrial use were reviewed. Based upon their own projected density of development for each land use, the Oyate then identified the potential number of lots which could be created within flood hazard areas given current land use regulations and controls.
Oglala Sioux Tribe	The Oglala Sioux Tribe Hazard Mitigation Plan does not provide information on growth and development.

Source: Local hazard mitigation plans

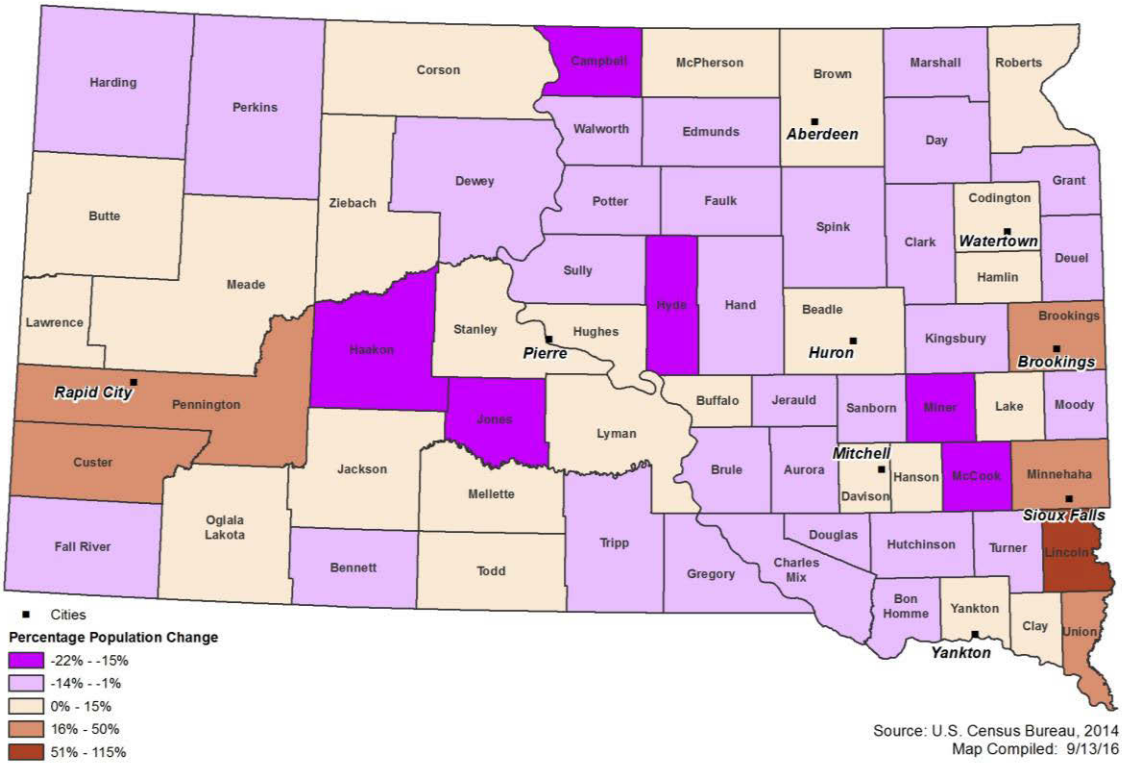
In addition to the trends noted in the hazard mitigation plans, plan reviewers commented on the following: Butte County is developing an ethanol plant and as a result experiencing a population increase.

Lawrence County is noticing growth in the Spearfish area. The discussion that follows focuses on population growth and housing unit trends and density by county, based on the most recent U.S. Census Bureau data.

Population

U.S. Census Bureau American Community Survey (ACS) estimates South Dakota's 2014 population at 853,175. This reflects an increase of 13% between 2000 and 2014. South Dakota ranked 46th among the 50 states in population in 2010, 25th in rate of growth from 2000 to 2010, 16th in land area, and 46th in population density in 2010. Figure 3-43 illustrates the estimated population changes (by percent) for the counties in the state between 2000-2014.

Figure 3-43 Estimated Percent Change in Population by County, 2000-2014



Decennial Census findings from the last few decades illustrate South Dakota's growth (see Table 3-35).

Table 3-35 South Dakota Decennial Census 1970-2010

Year	Population	% Change
1970	665,507	-2.2
1980	690,768	+3.8
1990	696,004	+.8
2000	754,844	+8.5
2010	814,180	+7.9

Source: U.S. Census Bureau

Between 2000 and 2011, 26 South Dakota counties gained population. With an estimated population gain of 85.8%, Lincoln County was the 4th fastest growing county in the United States (of counties with 10,000 or more in population) between 2000 and 2011 at 93.9% change in population. No counties in South Dakota were ranked among the top 100 largest (by population) in the U.S. The three largest counties in the state (Minnehaha, Pennington, and Lincoln) were in the Top 10 Counties that experienced the largest population growth by number and by percent gained. Table 3-36, Table 3-37, and Table 3-38 show the Top 10 South Dakota counties ranked by estimated population and those with the greatest estimated population gains.

Table 3-36 10 Largest Counties Ranked by Population (Estimated), 2011 and 2014

County	2011 Population	2014 Population
Minnehaha	171,752	182,882
Pennington	102,815	108,242
Lincoln	46,793	51,548
Brown	36,822	38,408
Brookings	32,226	33,314
Codington	27,442	27,938
Meade	25,546	26,951
Lawrence	24,312	24,657
Yankton	22,612	22,684
Davison	19,651	19,885

Source: U.S. Census Bureau American Community Survey 2011 Estimates

Table 3-37 Top 10 Counties with Greatest Estimated Population Gains (Numerical), 2000-2011 and 2010-2014

County	Population Gain 2000-2011	Population Gain 2000-2014
Minnehaha	23,471	34,601
Lincoln	22,662	27,417
Pennington	14,250	19,677
Brookings	4,006	5,094
Lawrence	2,510	2,855
Union	2,067	2,445
Codington	1,545	2,041
Oglala Lakota	1,462	1,752
Brown	1,362	2,948
Meade	1,293	2,698

Source: U.S. Census Bureau American Community Survey 2011 and 2014 Estimates

Table 3-38 Top 10 Counties with Greatest Estimated Population Gains (Percent), 2000-2011 and 2010-2014

County	Population Gain (%) 2000-2011	Population Gain (%) 2000-2014
Lincoln	93.9%	114%

County	Population Gain (%) 2000-2011	Population Gain (%) 2000-2014
Union	16.4%	19.4%
Pennington	16.1%	22.2%
Minnehaha	15.8%	23.3%
Custer	14.6%	16.1%
Brookings	14.2%	18.1%
Ziebach	13.2%	12.2%
Butte	12.8%	13.2%
Oglala Lakota	11.7%	14.1%
Lawrence	11.5%	13.1%

Source: U.S. Census Bureau American Community Survey 2011 and 2014 Estimates

Between 2000 and 2011, 40 South Dakota counties lost population. Of the counties with the most rapid losses, five of them (Campbell, Jones, Miner, Hyde, and Haakon) also rank among South Dakota's 10 least populous counties. Four counties reported rapid population loss in 2007. In the 2010 plan update, only two counties reported rapid population loss. This seemed to indicate that the State's population was stabilizing. Data from the 2011 American Community Survey Estimates suggests that several counties are experiencing rapid population decline again. Between 2010 and 2014, only 23 counties are estimated to be experiencing population loss. The analysis for 2010 to 2014 also shows that some counties like Pennington are predicted to have grown almost as much in four years as they had in 10 years.

Interim population projections issued by the U.S. Census Bureau in 2009 suggests that South Dakota's population will continue to grow but percentages will drop through 2020 (see Table 3-39). After 2020, population growth is projected to level off and begin to decline slightly after 2025. Population projections are only available at the state level. The U.S. Census Bureau has not updated this information and currently has no plans to produce a new set of state population projections.

Table 3-39 Interim South Dakota Population Projections, 2010-2030

Year	Projected Population	% Change
2010	786,399	+1.9
2015	796,954	+1.3
2020	801,939	+.6
2025	801,845	0
2030	800,462	-.2

Source: U.S. Census Bureau

Appendix 3A Population and Growth contains more population and growth information for all South Dakota counties.

Table 3-40 Top 10 Counties Ranked by Population Density, 2011 and 2014

County	2011 Estimated Population Density*	Population Density Change (%) 2000-2011	2014 Estimated Population Density	Population Density Change (%) 2000-2014	2011 Estimated Housing Density	Housing Density Change (%) 2000-2011
Minnehaha	212.8	15.6%	224.8	22.8%	90.2	20.8%
Lincoln	81.1	91.0%	89.1	113.7%	32.3	104.4%
Davison	45.1	4.9%	45.5	5.81%	20.4	9.8%
Yankton	43.4	4.7%	42.6	2.65%	18.6	9.6%
Brookings	40.7	14.2%	41.4	16.62%	17.0	16.4%
Codington	39.9	5.8%	39	3.45%	18.1	10.2%
Pennington	37.0	15.8%	38.9	21.94%	16.4	21.9%
Clay	34.1	4.0%	33.4	1.52%	13.7	3.6%
Union	31.8	16.3%	32.2	17.95%	13.8	19.0%
Lawrence	30.4	11.7%	30.8	12.82%	16.2	24.3%

Source: U.S. Census Bureau 2000 Census and American Community Survey 2011 Estimate

*Note: Density is reported as people/housing units per square mile and is based on the square mileage of each county's land area.

The percent change in population density tracks with the percent change in population growth. The fastest growing counties are also experiencing a more rapid increase in population density than the other counties. Determining areas of significant population density growth helps establish areas that may be more vulnerable to hazards due to the increased number of people living in a potentially impacted area.

Summary of Impact of Growth and Development Trends on Vulnerability and Loss Estimates

In general, counties with growing populations and number of housing units have an increased exposure to hazards not defined by specific geographic areas. These hazards may include winter storms, summer storms, tornadoes, wind, drought, wildfire, and earthquake. The counties experiencing the most development pressures all participate in the National Flood Insurance Program. Rapid City, in Pennington County, is in the Community Rating System at Class 7. This suggests that flood risk should not be increasing, assuming that county floodplain ordinances are being effectively implemented and wise use of floodplains encouraged. Three other cities in South Dakota were added to the Community Rating System Eligibility list in 2014. The city of Madison was added in May 2014 with a current rating of Class 8. The cities of Parkston and Spearfish were also added in May 2014 with Class 9 ratings. New data in Table 3-47 suggests that repetitive loss is increasing in the State. This may be mostly attributed to second homes. Union County is one of the fastest growing counties and also has potential for high flood losses as described in the flood vulnerability section. Growth and development trends and their impact on vulnerability were noted during stakeholder meetings held in conjunction with the 2007 update to the plan. Growth trends noted at that time included in Charles Mix County, where lodges were being built with potential risk to wildfire. New development in forested areas in Minnehaha County east of Sioux Falls are demanding city services for fire protection. New housing being built near Mitchell Lake and in North Lincoln County could also be at risk to wildfire. Values of homes in forested areas in the Black Hills are rising, thus the exposure analysis conducted for this plan is likely to underestimate the property

values exposed to wildfire risk. New homes being built in Meade and other Counties increase the exposure to damage from tornadoes.

Social Vulnerability

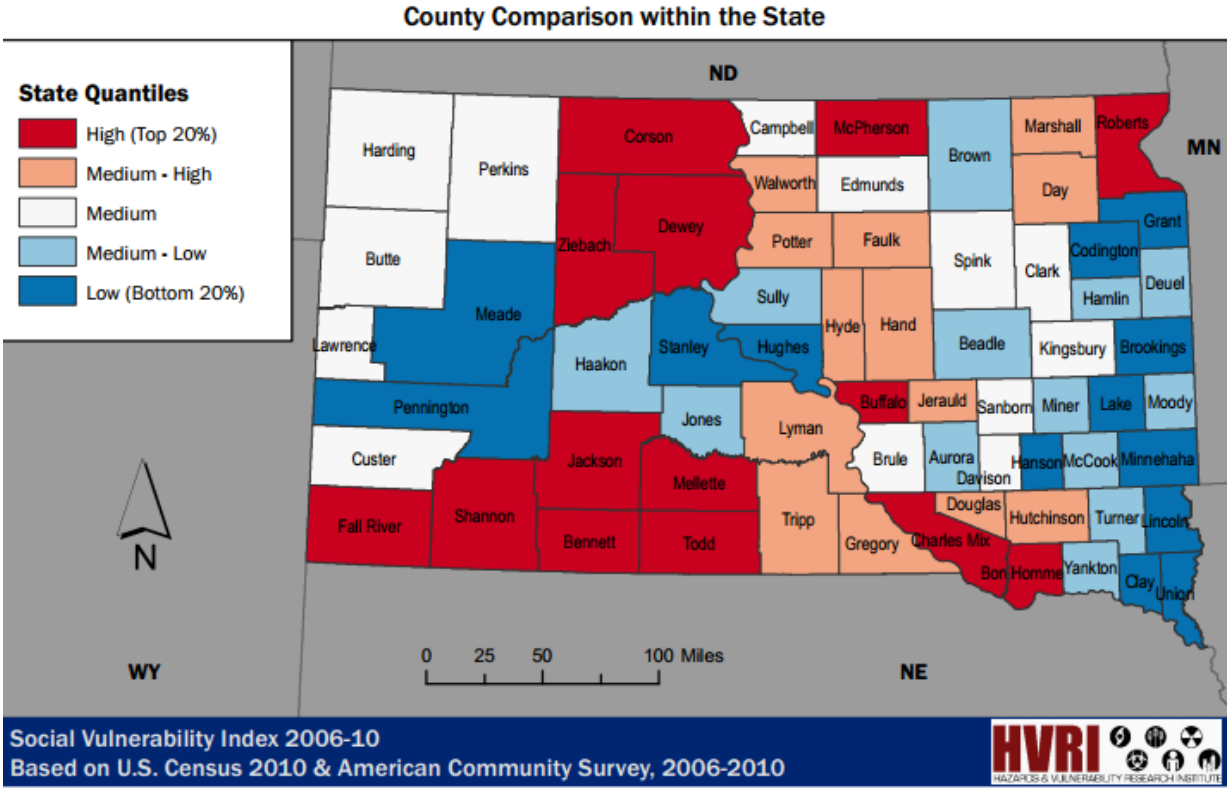
A Social Vulnerability Index (SoVI) compiled by the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina measures the social vulnerability of U.S. counties to environmental hazards. The comparison of SoVI values between counties within the state allows for a more detailed depiction of variances in risk and vulnerability. The Index is based on national data sources, primarily the 2010 census, and synthesizes 30 socioeconomic variables that research literature suggests contribute to reduction in a community's ability to prepare for, respond to, and recover from hazards. Seven components differentiate counties according to their relative level of social vulnerability. The components include race and class, wealth, elderly residents, Hispanic ethnicity, special needs individuals, Native American ethnicity, and service industry employment.

The index can be used by the state to help determine where social vulnerability and exposure to hazards overlaps and how and where mitigation resources might best be used. See Figure 3-44 for a map that illustrates South Dakota's geographic variation in social vulnerability. According to the index, the following, listed in order, are South Dakota's most socially vulnerable counties (i.e., they rank in the top 20 percent in the state):

- Buffalo
- Todd
- Oglala Lakota*
- Jackson
- Mellette
- McPherson
- Bennett
- Ziebach*
- Corson
- Fall River
- Dewey
- Charles Mix
- Bon Homme
- Roberts

*Note: An asterisk (*) denotes counties that are among the 10 fastest growing counties in the state. The counties of Potter, Faulk, Lyman, Gregory, Jerauld, Walworth, Douglas, Day, Hyde, Hand, Hutchinson, Tripp, Marshall, Perkins, Spink, and Edmunds also rank in the top 20 percent in the nation in terms of social vulnerability.

Figure 3-44 Social Vulnerability to Environmental Hazards, County Comparison within the State, 2006-2010



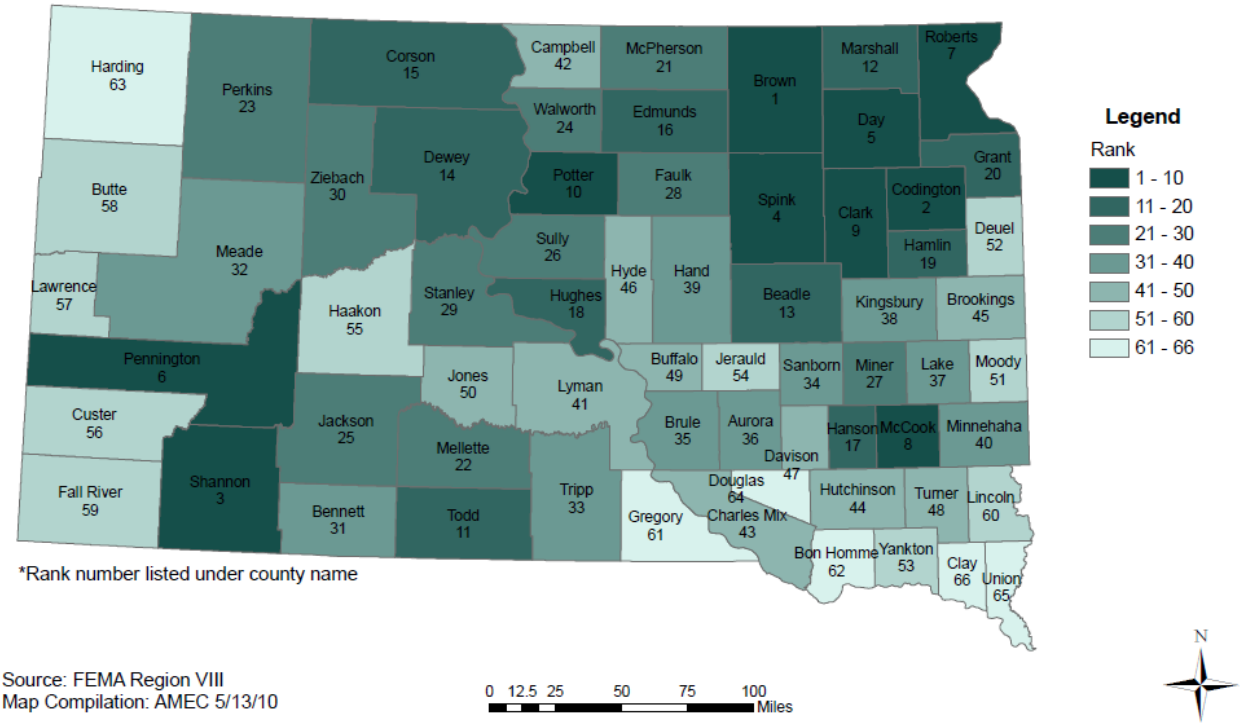
Federal Disaster Declaration History and Analysis

Another indicator of vulnerability by jurisdiction is looking at the pattern of past disaster declarations by county across the State. FEMA Region VIII made available summary counts of the number of Individual Assistance (IA) and Public Assistance (PA) claims. These summaries are presented on the maps in for the time period of July 1993 to May 2009 for the IA claims and 1993 to 2014 for the PA claims. 2009 IA claims were still represent the last major disaster with IA at the time the 2016 HIRA update.

The tables below summarize PA claims data for major disaster declarations in South Dakota since 1993 by disaster declaration and by category of assistance. Based on this data the majority of PA funding is for public utilities damage, roads and bridges and emergency protective measures. The public utilities damage is largely damage from winter storms or wind storms that result in downed power lines, broken power poles, or disrupted electrical distribution/transmission lines. The State is actively investing hazard mitigation funding (both under PA and HMGP) into electric utilities, which appears to be a worthwhile investment given patterns of past damages and claims. See the discussion on Rural Electric Cooperatives later in this section for more on the use of PA Section 406 funding and Hazard Mitigation Grant Program funding used to assist with mitigation and retrofitting of power infrastructure. The roads and bridges infrastructure damage largely represents flood related damages, including washed out gravel roads and culverts, and only represents a portion of the true disaster losses. There is another federal program under

the Federal Highways Administration that also has been used for emergency repairs. This data could be obtained to further enhance this analysis in future updates.

Figure 3-45 FEMA Individual Assistance Claims 1993-2009



Source: FEMA Region VIII

Table 3-41 PA Claims Summary by FEMA Disaster Declaration

DR Number	DR Date	Type	PA Claims	Federal Share
999	1993	Flooding, Severe Storms, Tornadoes	30	$189,348
1031	1994	Severe Storms, Flooding	76	$600,788
1052	1995	Severe Storms, Flooding	452	$4,413,670
1173	1197	Severe Storms, Flooding, (High Winds)	426	$4,562,310

1218	1998	Flooding, Severe Storms, Tornadoes	334	$2,167,556
1375	2001	Severe Storms (flooding)	40	$285,209
1702	2007	Severe Storms, Tornadoes, Flooding	40	$298,511
1759	2008	Severe winter storm and record snowstorm	26	-$2,564,764
1774	2008	severe storms and flooding	984	$5,347,222
1811	2008	Severe winter storm and record and near record snow	55	$2,208,421
1844	2009	Severe Storms and Flooding	5,445	$45,729,602
1886	2010	Severe Winter Storm and Snowstorm	94	$791,571
1887	2010	Severe Winter Storm	524	$9,995,553
1914	2010	Severe Winter Storm	11	-$64,449
1915	2010	Flooding	2,601	$24,003,797
1929	2010	Severe Storms, Tornadoes, and Flooding	208	$1,683,662
1938	2010	Severe Storms and Flooding	466	$3,513,639
1984	2011	Severe Storms and Flooding	5,219	$60,955,070
4115	2013	Severe winter storm and snowstorm	71	$10,291,644
4125	2013	Severe Storms, Tornado, and Flooding	207	$6,720,666
4137	2013	Severe Storms, Tornado, and Flooding	147	$2,125,942
4155	2013	Severe Storms, Tornado, and Flooding	858	$520,741,648
4186	2014	Severe storms, tornadoes, flooding	630	$54,602,136
Total			**18,944**	**$758,598,752**

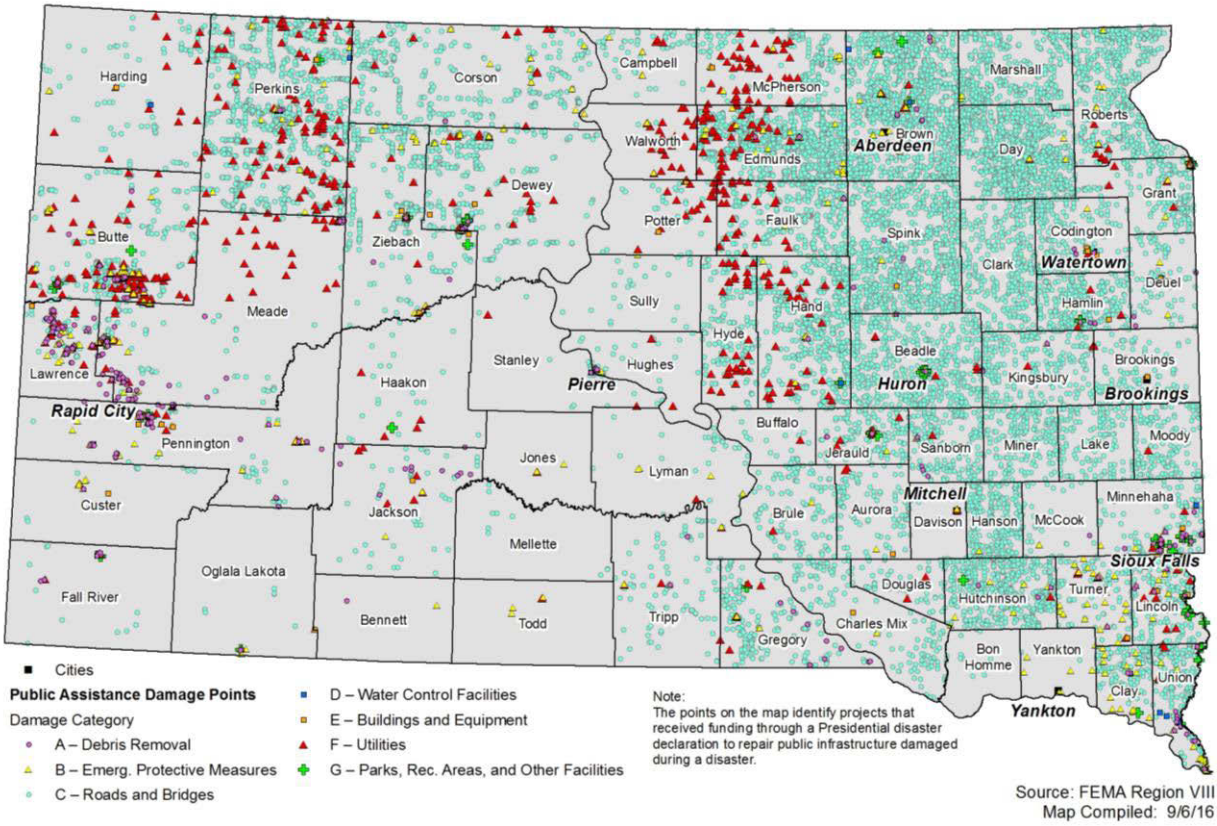
*FEMA-1984-DR was not included as it was IA only

Table 3-42 PA Disaster Expenditures Summarized by Damage Categories

Damage Category	Counts	Federal Share

A – Debris Removal	342	$26,995,425
B – Emerg. Protective Measures	639	$47,947,340
C – Roads and Bridges	16,935	$203,909,386
D – Water Control Facilities	19	$1,063,263
E – Buildings and Equipment	98	$1,085,549
F – Utilities	807	$466,422,028
G – Parks, Rec. Areas, and Other Facilities	75	$11,175,449
Uncategorized	29	$312
Total	**18,944**	**$758,598,752**

Figure 3-46 FEMA Public Assistance Damage Sites by Damage Category 1993-2016



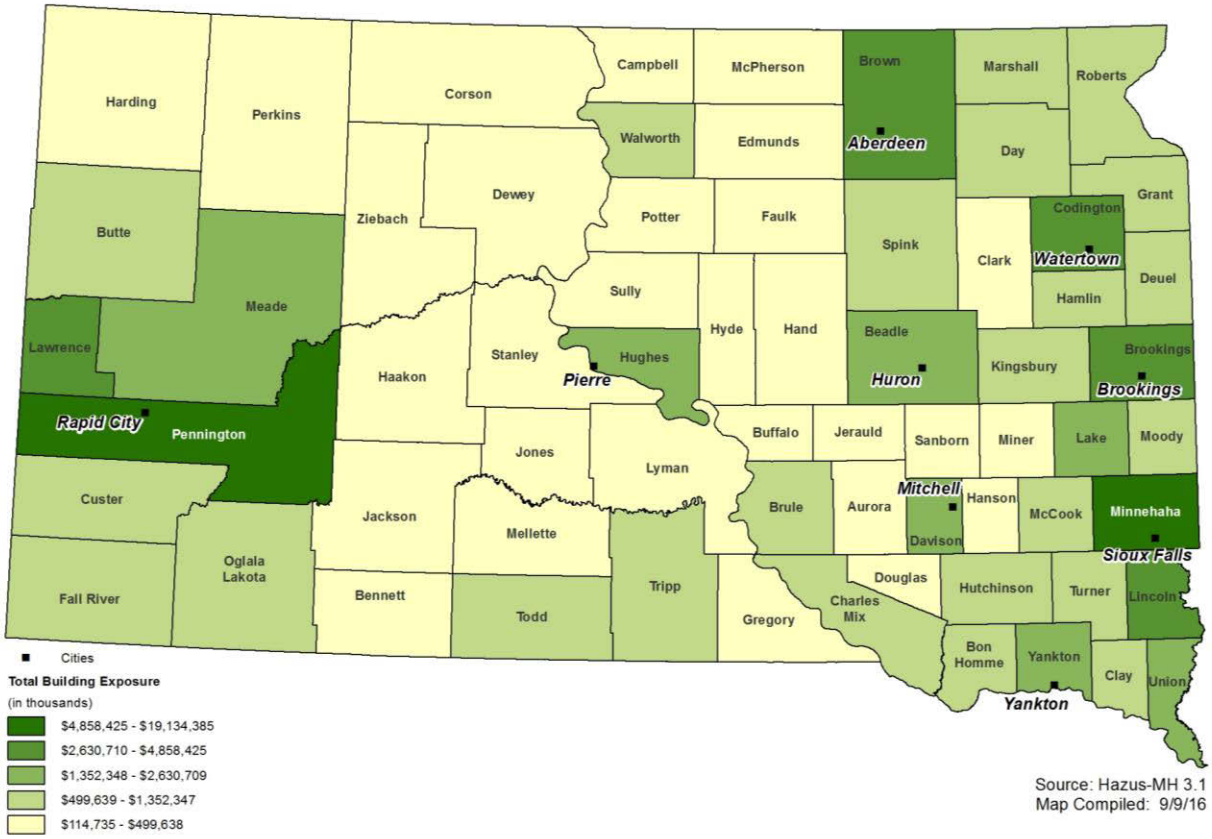
Source FEMA Region VIII/SD OEM

Building Exposure

Exposure is a term borrowed from the insurance industry as a measure of property "exposed" to a particular hazard. HAZUS-MH Ver. 3.1 building inventory data provided the basis for measuring the number and value of buildings vulnerable to hazards. There are an estimated 343,736 buildings in South Dakota with a total building replacement value (excluding contents) of $89,567,051,000. Approximately 92 percent of the buildings (and 70 percent of the building value) are associated with residential housing. Figure 3-47 shows a thematic map at how building exposure varies by county across the state.

In terms of a catastrophic event, the entire building inventory could be at risk to a hazard. An event that would destroy or damage the entire inventory in a given county is unlikely, but it is possible that a tornado impacting the heart of a rural community could result in considerable building losses.

Figure 3-47 Building Exposure 2016



Agricultural Pest and Diseases

This hazard was added to the plan in 2010, and retained for the 2013 and 2016 HIRA updates. This hazard includes a number of different pests and diseases that could affect the agricultural industry in South Dakota. The types of impacts will vary from year to year and county to county, but it is anticipated that the agricultural industry will continue to suffer losses from the various pests and diseases. Economically, these impacts can total up to a billion dollars in the State. Outside of the economic impacts, some of these have the potential to affect human health as well, as noted in in the Agricultural Pest and Diseases hazard profile. Average annual crop loss can be estimated based on indemnity data from the RMA. Between 2003 and 2015, there was a total of $9,626,082 in indemnity payments in insect infestation with an annual loss of $740,468. There was a total of $6,713,015 in indemnity payments between 2003 and 2015 in plant disease with an annual loss of $516,386.

Annual cattle death loss is more difficult to estimate accurately given the report increments and absence of state level data in 2005 and 2000. Averages of the data from 2011, 1995, and 1991 indicate that South Dakota could expect to lose 60,866 cattle and 120,866 calves to combined predator and non-predator causes in any given year. This includes 7,822 cattle and 27,306 calves lost to digestive problems in any

given year, and 17,316 cattle and 29,193 calves lost to respiratory problems in any given year. At a value of $1,133 per head for cattle and $381 per head for calves, South Dakota's cattle industry losses in 2010 totaled $52,384,926 due to respiratory, digestive, and other diseases. Total dollar value per head was not provided in the 1995 and 1991 reports. Additional outreach to the South Dakota Animal Industry Board during 2013 did not yield updated or more specific impact data. Further analysis of the risk and potential loss from these hazards should be considered in future updates to this plan.

The following figures show the total market value of crops sold in 2012 and cattle inventories by county as an indicator of exposure to agricultural pest and diseases. The counties with higher values rely more heavily and directly on crops and cattle economically. Crop producers and ranchers can see increased damages and therefore significantly diminished profits caused by agricultural pests and diseases. The counties with the highest crop exposure values include Roberts, Spink and Brown. These counties have a crop exposure value between $200 million and $460 million. Edmunds, Day, Faulk, Clark, Sully, Hand, Beadle, Kingsbury, Brookings, and Minnehaha all have a crop exposure value between $1.5 million and $2 million. The counties with the highest market value of livestock include Marshall, Spink, Beadles, Kingsbury, Grant, Brookings, Minnehaha, Huchinson,, Charles Mix, Tripp, and Fall River. Counties with a total market value of livestock between $75 million and $100 million include Meade, Perkins, Edmunds, Hand, Clark, Deuel, Moody, Douglas, and Turner.

Figure 3-48 Total Market Value of Crops Sold by County

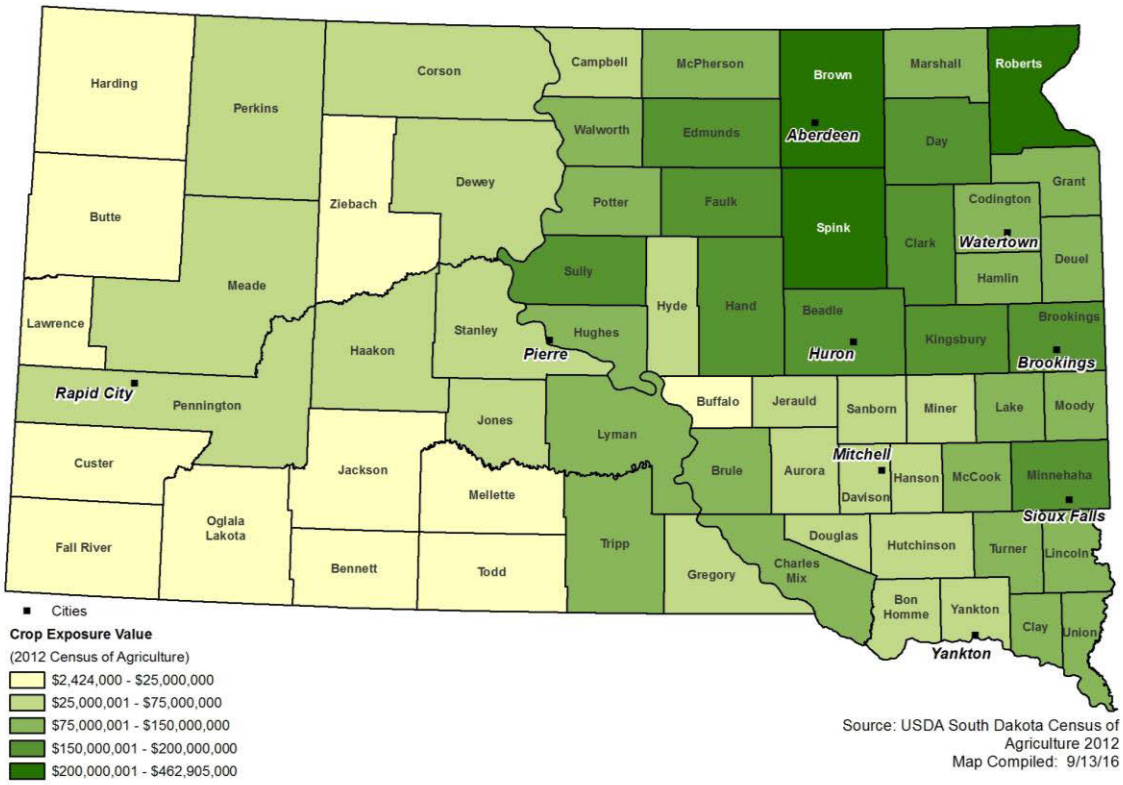
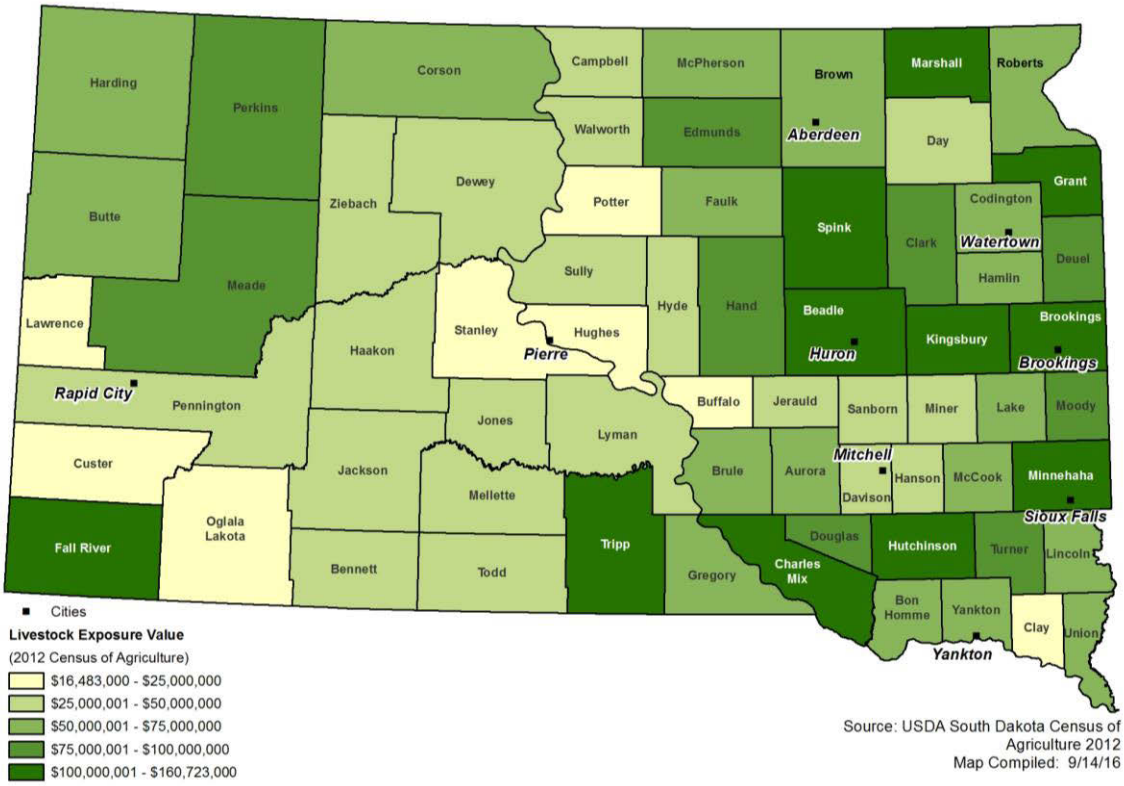


Figure 3-49 Total Market Value of Livestock Sold by County in 2012



Future Vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%.

Table 3-43 Consequence Summary for Agricultural Pest and Disease

Category	Narrative
Impact on the Public	Potential for animal to human transfer of disease; potential for loss of livelihoods; potential for mental health issues due to severe economic hardship
Impact on the Economic	Potentially devastating depending on the pest or disease and its impacts; disease can wipe out whole herds; pests or disease can wipe out crops;

Condition of the State	incident may disrupt business operations of farms statewide; impacts could come from an incident in the state, or an incident in a nearby state; agriculture economy can be affected by something as simple as an unchecked rumor
Impact on the Environment	Zoonotic animal diseases may spread between livestock and wildlife; crop diseases or pests may spread between crops and surrounding flora; potential for widespread impacts depending on parameters of incident
Impact on Property, Facilities, and Infrastructure	No physical impacts to property; infected crops or livestock may be barred from slaughterhouses, co-ops, markets and other agriculture sites
Impact on the Public Confidence in Government	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective
Impact on Responders	Isolation or quarantine can stress first responders needed to close roads or provide security
Impact on Continuity of Operations	Need for personnel may stress limited resources
Cascading Hazards	N/A

Floods

Nearly every county in South Dakota is vulnerable to floods. South Dakota's January 2004 Map Modernization Plan divides the state into five regions based on population and flooding hazards. The priority regions and the jurisdictions associated with those regions are:

- **Priority 1: Big Sioux Region**—Brookings, Clark, Clay, Codington, Day, Deuel, Grant, Hamlin, Hutchinson, Kingsbury, Lake, Lincoln, Marshall, McCook, Miner, Minnehaha, Moody, Roberts, Turner, Union, and Yankton.
- **Priority 2: James Region**—Aurora, Beadle, Bon Homme, Brown, Brule, Buffalo, Campbell, Charles Mix, Davison, Douglas, Edmunds, Faulk, Hand, Hanson, Hughes, Hyde, Jerauld, McPherson, Potter, Sanborn, Spink, Sully, and Walworth*.
- **Priority 3: Grand/Moreau Region**—Butte, Corson, Dewey, Harding, Meade, Perkins, and Ziebach.
- **Priority 4: Cheyenne Region**—Custer, Fall River, Haakon, Lawrence, Pennington, Oglala Lakota, and Stanley.
- **Priority 5: White/Bad Region**—Bennett, Gregory, Jackson, Jones, Lyman, Mellette, Todd, and Tripp.

The following section describes progress the State has made developing vulnerability and loss estimates for the highlighted counties. Future updates to this plan will include additional vulnerability analyses as more DFIRMs become available and as more resources for HAZUS-MH studies are obtained.

Methodology

Planning level flood loss estimates were made available for every county in South Dakota with the 2010 update to the South Dakota Hazard Mitigation Plan. These estimates were still relevant for the 2013 update. FEMA used HAZUS-MH MR2 to model the 100-year floodplain and perform associated building and population risk assessments. HAZUS-MH is FEMA's GIS-based natural hazard loss estimation software. The HAZUS-MH flood model results included analysis for each of the 66 counties modeling streams draining a 10 square mile minimum drainage area, using 30 meter (1 arc second) Digital Elevation Models (DEM). Hydrology and hydraulic processes utilize the DEMs, along with flows from USGS regressions and gauge data, to determine reach discharges and to model the floodplain. Losses are then calculated using HAZUS-MH national baseline inventories (buildings and population) at the census block level.

HAZUS-MH produces a flood polygon and flood-depth grid that represents the 100-year floodplain. The 100-year floodplain represents a flood that has a 1% chance of being equaled or exceeded in any single year. While not as accurate as official flood maps, these floodplain boundaries are available for use in GIS and could be valuable to communities that have not been mapped by the National Flood Insurance Program. HAZUS-MH generated damage estimates are directly related to depth of flooding and are based on FEMA's depth-damage functions. For example, a two-foot flood generally results in about 25 percent damage to the structure (which is based on 25 percent of the structure's replacement value). The HAZUS-MH flood analysis results provide number of buildings impacted, estimates of the building repair costs, and the associated loss of building contents and business inventory. Building damage can cause additional losses to a community as a whole by restricting the building's ability to function properly. Income loss data accounts for losses such as business interruption and rental income losses as well as the resources associated with damage repair and job and housing losses.

Data Limitations: Potential losses derived from HAZUS-MH used default national databases and may contain inaccuracies; loss estimates should be used for planning level applications only. There could also be errors and inadequacies associated with the hydrologic and hydraulic modeling of the HAZUS-MH model. In rural South Dakota, census blocks are large and often sparsely populated or developed; this may create inaccurate loss estimates. HAZUS-MH assumes population and building inventory to be evenly distributed over a census block; flooding may occur in a small section of the census block where there are not actually any buildings or people, but the model assumes that there is damage to that block. In addition, excessive flood depths may occur due to problems with a DEM or with modeling lake flooding. Errors in the extent and depth of the floodplain may also be present from the use of 30 meter digital elevation models. HAZUS-MH Level II analyses based on local building inventory, higher resolution terrain models, and DFIRMs could be used in the future to refine and improve the accuracy of the results. Another limitation is that HAZUS does not model lake shore flooding and may not represent the closed basin flooding scenarios common in South Dakota, as in Brown County. HAZUS level 1 modeling does not account for levee protection.

HAZUS-MH building data is based on average housing costs and 2000 census counts. There may be errors within the HAZUS-MH data itself. The size and shape of the census block affects the accuracy of this model. The larger and more irregular the census block, typically found in rural areas, the less accurate this method becomes. There could be spatial inaccuracies with DFIRM data, or the data may not include all the possible flood hazards within a particular county. This model may include structures

within the 100-year floodplain (A Zone) that may be elevated above the level of the base flood elevation, according to local floodplain development requirements. This model may not reflect actual real world conditions, but it does serve as a basis to quantify the possible risk from floods, using the best available data.

HAZUS-MH produces a flood polygon and flood-depth grid that represents the base flood. While not as accurate as official flood maps, such as digital flood insurance rate maps, these floodplain boundaries are available for use in GIS and could be valuable to communities that have not been mapped by the National Flood Insurance Program. A statewide digital flood hazard layer was created by appending floodplain boundaries created in each county run and is displayed in Figure 3-51 Figure 3-50 shows the current extent of effective DFIRMs in the State.

Figure 3-50 South Dakota Digital Flood Insurance Rate Map Coverage 2016

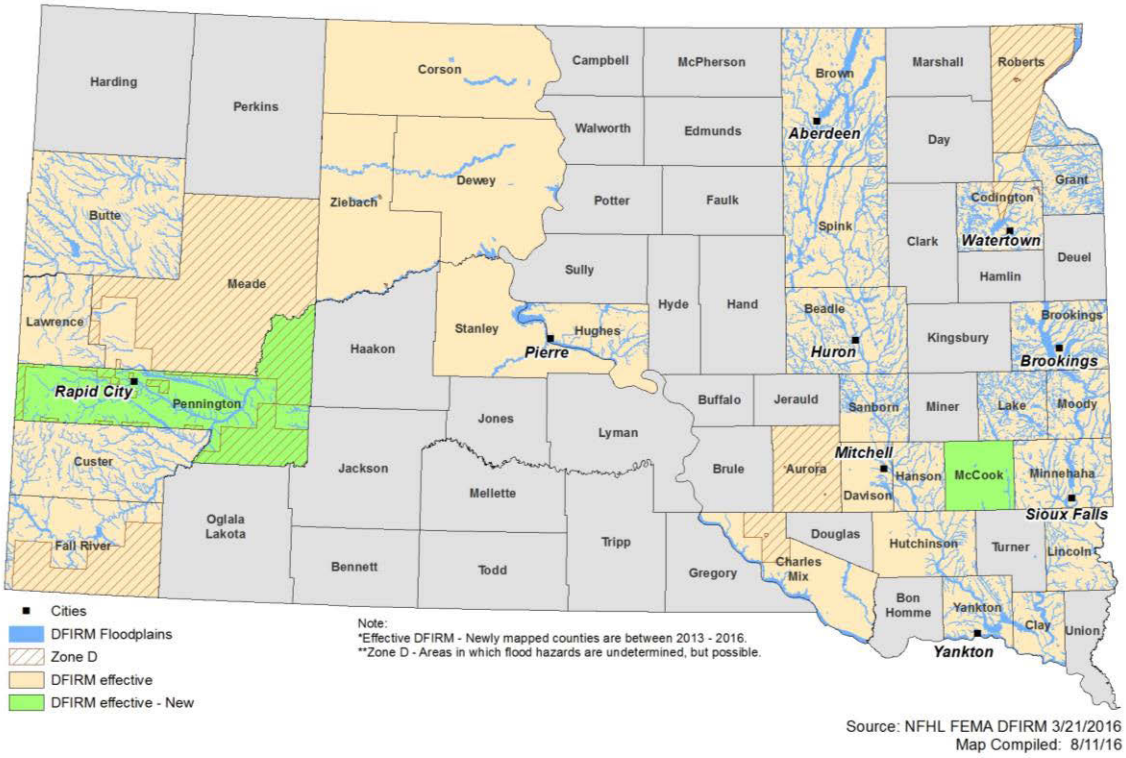


Figure 3-51 South Dakotas 100-year Flood Zones based on HAZUS

Vulnerable Jurisdictions and Potential Losses

The intent of this analysis was to enable the state to estimate where flood losses could occur and quantify the degree of severity using a consistent methodology. The computer modeling helps quantify risk along known flood hazard corridors such as along the James, Big Sioux, and Vermillion rivers. In addition, flood losses are estimated for certain lesser streams and rivers where the flood hazard may not have been previously studied.

HAZUS-MH impact analyses were run for direct economic losses for buildings and societal impacts (displaced people and shelter needs) to display the relative ranking of counties based on these risk indicators (these losses and impacts are illustrated in the tables that follow). The primary indicators used to assess flood losses were:

- Direct building losses combined with income losses,
- Loss ratio of the direct building losses compared to overall building inventory,
- Loss ratio of building contents compared to overall building inventory, and
- Population displaced by the flood and shelter needs.

The results, shown in Table 3-44, Figure 3-52, Figure 3-53, Figure 3-54, and Figure 3-55, display the potential base flood losses to all counties. More detailed results are in Appendix 3B. The results show potential losses as highest in Minnehaha, Union, Yankton, Pennington, Codington, Lawrence and Brown

counties. Floods in these counties have the potential to displace at least a thousand persons in each county. Statewide there is the potential for $1.7 Billion in flood losses from the 1% annual chance flood.

Based on the loss ratio, which is the percent of the total building inventory value that could be damaged from flooding in any given year, Union, Yankton, Fall River and Campbell Counties are most at risk and may have difficulty recovering from a flood event. Note that Union County does contain levees (see the flood hazard profile section), which is likely being ignored by HAZUS. The results presented for Union County may be more representative of a levee failure scenario.

Table 3-44 HAZUS-MH Base Flood (1 Percent Chance) Loss Estimation Results: Impacts by County, Ranked by Highest Building Losses

County Name	Building Damage Count	Building Damage Loss ($K)	Building Damage Loss Ratio*	Contents Damage Loss ($K)	Contents Loss Ratio	Total Direct Econ Bldg Loss **($K)	Short Term Shelter Needs	Displaced Population
Minnehaha	719	162,527	1.6%	252,358	3.6%	432,484	6,159	7,482
Union	867	119,836	11.6%	203,473	25.4%	349,991	3,451	4,428
Yankton	713	81,492	5.6%	105,103	9.7%	193,250	2,614	3,328
Pennington***	88	15,085	0.32%	33,970	0.4%	113,162	888	1,301
Codington	221	28,917	1.7%	48,403	3.9%	81,843	2,301	3,027
Lawrence	72	20,631	1.5%	28,237	3.0%	50,103	504	979
Brown	71	16,502	0.7%	22,083	1.4%	40,502	854	1,785
Stanley	131	14,974	9.2%	11,356	10.9%	26,644	340	666
Fall River	92	14,007	3.2%	20,735	7.5%	36,379	250	525
Butte	24	9,890	2.3%	10,891	4.0%	21,428	271	892
Lake	72	8,740	1.1%	11,306	2.1%	20,840	664	1,128
Oglala Lakota	34	8,180	2.5%	11,173	5.1%	20,430	492	1,214
Lincoln	26	7,275	0.5%	6,826	0.7%	14,514	210	524
Spink	15	6,474	1.3%	7,554	2.4%	14,644	217	572
Davison	24	6,417	0.6%	6,297	0.8%	13,185	216	530
Hutchinson	29	5,799	1.2%	9,436	2.6%	16,001	646	957
Turner	12	5,659	0.9%	7,748	1.9%	14,191	39	391
Hamlin	18	5,398	1.4%	9,963	4.0%	16,441	31	387
Custer	6	5,092	1.1%	10,476	3.7%	16,746	44	257
Meade	8	4,808	0.4%	6,458	0.8%	11,765	106	469
Brookings	7	4,563	0.3%	9,953	0.8%	15,476	383	943
Grant	22	4,422	0.9%	4,652	1.4%	9,592	97	415
Charles Mix	4	4,020	0.7%	5,337	1.4%	9,842	46	232

County Name	Building Damage Count	Building Damage Loss ($K)	Building Damage Loss Ratio*	Contents Damage Loss ($K)	Contents Loss Ratio	Total Direct Econ Bldg Loss **($K)	Short Term Shelter Needs	Displaced Population
Aurora	17	3,914	2.0%	5,561	4.5%	10,125	101	481
Haakon	13	3,761	2.6%	5,756	5.3%	10,151	78	303
Beadle	6	3,673	0.3%	6,000	0.8%	10,393	64	387
Tripp	31	3,470	0.9%	3,446	1.3%	7,248	86	265
Campbell	37	3,393	3.2%	5,017	7.1%	8,813	124	383
Lyman	13	3,267	1.5%	3,329	2.3%	6,876	38	145
McCook	18	3,257	0.9%	2,680	1.1%	6,096	65	252
Hughes	7	3,195	0.3%	5,319	0.7%	8,871	297	611
Clay	18	2,952	0.4%	2,268	0.5%	5,327	88	248
Roberts	8	2,903	0.5%	3,991	1.0%	7,273	36	320
Edmunds	30	2,718	1.0%	2,526	1.4%	5,461	156	293
Todd	9	2,227	0.8%	3,458	1.9%	5,723	105	314
Corson	16	2,089	1.5%	1,711	1.9%	3,894	285	446
Hand	9	2,083	0.7%	1,931	1.0%	4,161	39	197
Moody	2	2,072	0.5%	1,949	0.8%	4,220	9	216
Bon Homme	7	1,815	0.4%	1,870	48.9%	3,828	37	117
Day	5	1,649	0.3%	1,386	0.5%	3,187	10	157
Dewey	3	1,532	0.8%	981	0.9%	2,557	31	166
Miner	9	1,527	0.8%	1,685	1.4%	3,363	66	159
Mellette	14	1,501	1.9%	817	1.6%	2,331	109	223
Brule	1	1,423	0.4%	1,813	0.7%	3,498	19	151
Ziebach	8	1,403	2.1%	749	1.9%	2,158	75	191
Deuel	2	1,386	0.5%	2,256	1.2%	3,922	34	154
Hanson	0	1,368	0.8%	1,029	0.9%	2,473	3	94
Kingsbury	0	1,366	0.3%	2,080	0.8%	3,672	48	281
Perkins	0	1,293	0.6%	982	0.7%	2,339	-	76
Faulk	4	1,275	0.8%	1,592	1.4%	3,056	94	179
Clark	2	1,208	0.5%	1,880	1.1%	3,328	45	159
Bennett	0	1,165	1.0%	1,808	2.3%	3,145	2	71
Sanborn	0	1,121	0.7%	1,121	1.0%	2,400	3	142
Marshall	0	1,062	0.3%	1,052	0.5%	2,223	7	143
Douglas	5	984	0.5%	1,163	0.9%	2,342	14	152
Walworth	0	780	0.2%	786	0.3%	1,632	-	63
Jackson	0	702	0.6%	723	1.0%	1,445	3	69
Buffalo	1	645	1.1%	631	1.5%	1,347	30	79
McPherson	0	628	0.3%	815	0.6%	1,545	4	95
Jerauld	0	591	0.3%	833	0.7%	1,534	8	77

County Name	Building Damage Count	Building Damage Loss ($K)	Building Damage Loss Ratio*	Contents Damage Loss ($K)	Contents Loss Ratio	Total Direct Econ Bldg Loss **($K)	Short Term Shelter Needs	Displaced Population
Potter	0	537	0.2%	781	0.4%	1,416	1	44
Harding	0	504	0.6%	516	1.0%	1,045	2	43
Sully	0	502	0.4%	456	0.6%	1,016	1	42
Gregory	0	474	0.2%	254	0.1%	731	-	44
Hyde	0	292	0.3%	370	0.5%	709	-	39
Jones	1	288	0.4%	243	0.5%	551	-	17
	3,571	634,703	1.3%	929,402	3%	1,706,878	22,876	40,598

Source: FEMA Region VIII HAZUS-MH MR2 Notes:
*Loss ratio is the percent of the total building inventory value that could be damaged from flooding in any given year.
**Total Direct Economic loss includes relocation loss, capital-related loss, wages loss, rental income loss and building loss.
***Added from South Dakota Emergency Management HAZUS run to account for problem reach in FEMA analysis

Figure 3-52 HAZUS-MH Base Flood (1 Percent Chance) Building and Income Loss Estimation by County

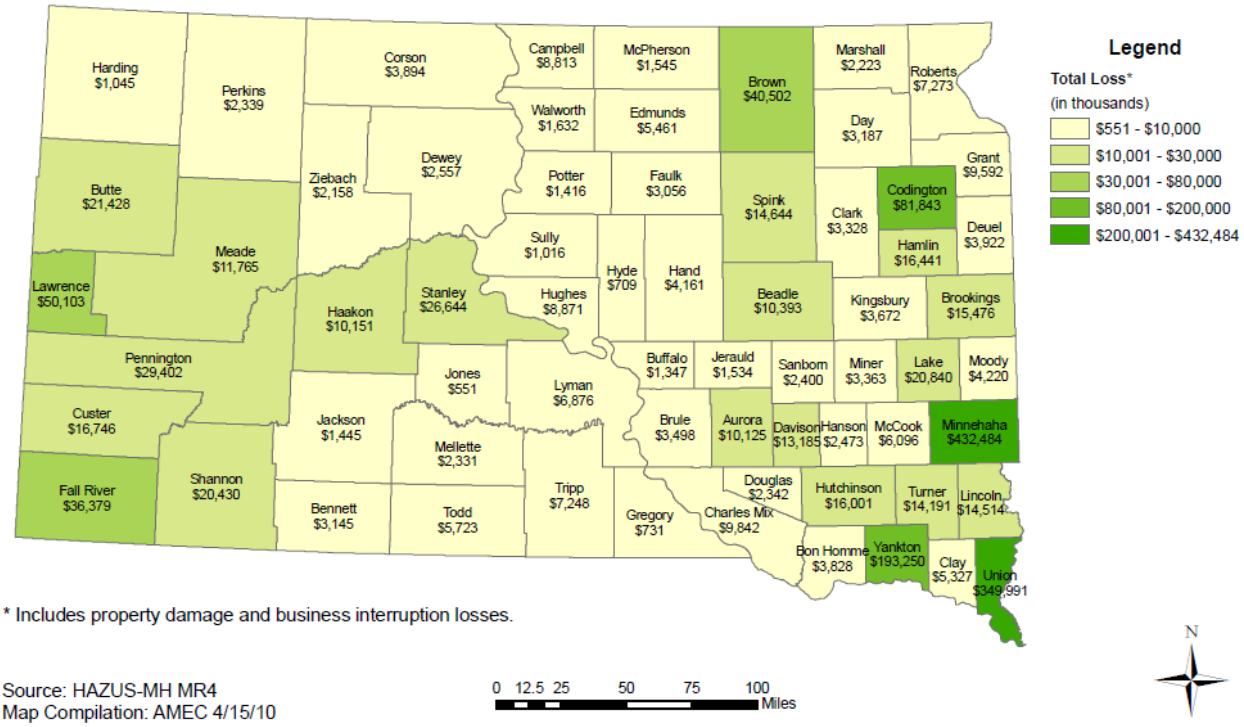
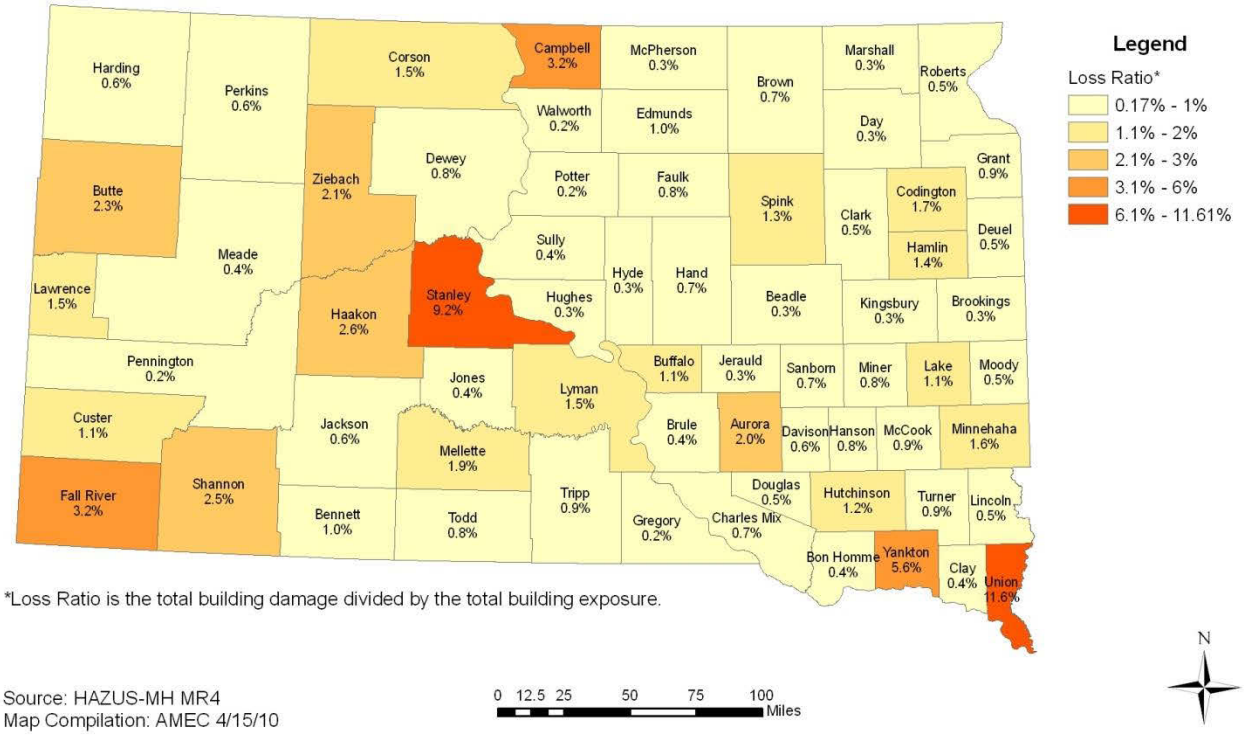
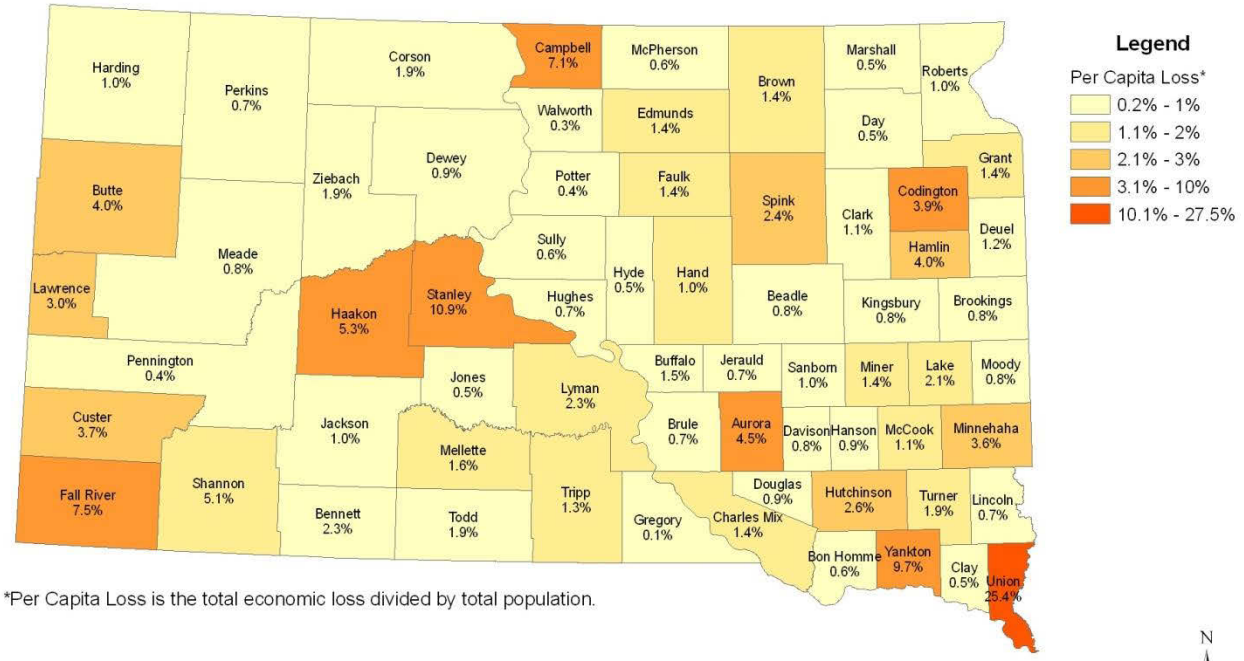


Figure 3-53 HAZUS-MH Base Flood (1 Percent Chance) Building Loss Ratio



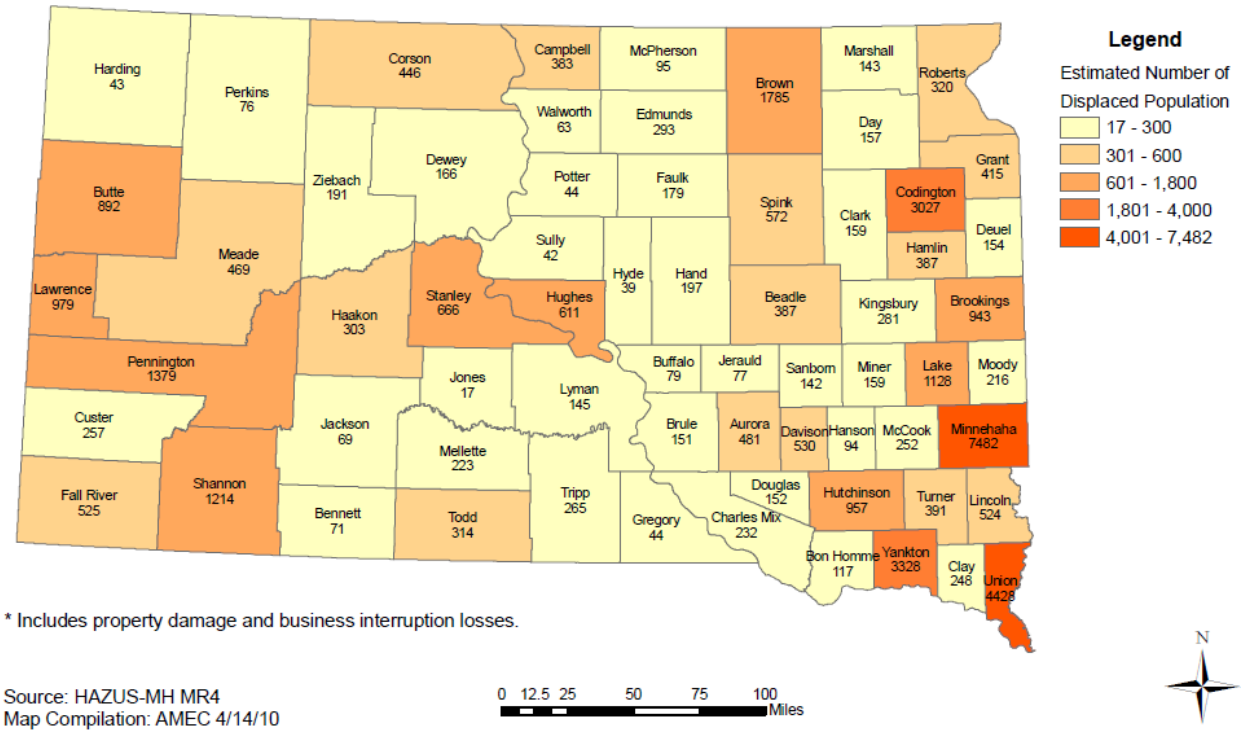
Source: HAZUS-MH MR4
Map Compilation: AMEC 4/15/10

Figure 3-54 HAZUS-MH Base Flood (1 Percent Chance) Content Loss Ratio



Source: HAZUS-MH MR4
Map Compilation: AMEC 4/15/10

Figure 3-55 HAZUS-MH Base Flood (1 Percent Chance) Displaced Population Estimation by County



A separate methodology was used in 2007 and updated in 2013 to analyze those counties with existing DFIRMs. Using GIS, the DFIRM special flood hazard area boundaries were overlaid on HAZUS-MH building inventory, which is linked to census block geography. A proportional division was performed to account for blocks that were split by flood boundaries, and to better model values in the floodplain. For example, a census block that was split in two by a floodplain (50 percent in, 50 percent out) had its building count and valuation attributes multiplied by 0.50. From this method, information on the number of buildings and building replacement value at risk could be estimated by county and by flood zone.

The DFIRM loss estimation results are presented separately in Table 3-45. The DFIRM floodplains should be more accurate, but in some cases not as extensive, as the HAZUS-MH generated floodplains. Some DFIRMs are community-based only and do not cover the entire county. McCook County was the only county with new DFIRM in 2016. The county's DFIRM was imported into HAZUS 3.1 Enhanced Quick Look to generate the loss estimate.

Table 3-45 Digital Flood Insurance Rate Maps Base Flood (1 Percent Chance) Loss Estimations

County	Percent of County in Floodplain	Building Count	Total Exposure	Estimated Flood Loss
Minnehaha	12.86%	4,508	$1,700,878,282	$425,219,570
Pennington	2.26%	2,627	$554,516,791	$138,629,198
Codington	3.70%	1,961	$387,336,901	$96,834,225
Brown	13.56%	1,534	$278,794,681	$69,698,670
Brookings	8.99%	1,088	$202,465,157	$50,616,289
Yankton	11.93%	824	$192,415,451	$48,103,863
Lawrence	1.22%	903	$162,485,138	$40,621,284
Meade	1.63%	709	$148,200,897	$37,050,224
Lake	3.88%	747	$121,188,376	$30,297,094
Hughes	2.67%	354	$95,424,076	$23,856,019
Lincoln	5.23%	444	$88,456,803	$22,114,201
Custer	1.71%	449	$88,280,833	$22,070,208
Stanley	1.82%	558	$73,146,476	$18,286,619
Roberts	10.08%	464	$69,161,018	$17,290,255
Moody	8.70%	445	$59,291,843	$14,822,961
Spink	7.22%	414	$55,893,903	$13,973,476
Butte	1.44%	408	$55,729,397	$13,932,349
Fall River	2.02%	238	$55,237,998	$13,809,500
Beadle	6.56%	394	$51,825,695	$12,956,424
Davison	11.42%	297	$50,427,520	$12,606,880
Grant	2.05%	313	$49,909,217	$12,477,304
Hutchinson	8.46%	198	$29,063,726	$7,265,932
Sanborn	3.28%	168	$23,740,640	$5,935,160
Charles Mix	12.22%	164	$21,228,852	$5,307,213
Clay	21.00%	137	$18,929,360	$4,732,340
McCook*	0.01%	16	$613,226,000	$2,198,000
Aurora	11.17%	66	$9,353,611	$2,338,403
Hanson	7.93%	91	$8,802,869	$2,200,717
Corson	3.67%	70	$7,451,377	$1,862,844
Ziebach	4.33%	71	$5,565,882	$1,391,471
Dewey	4.50%	49	$4,629,792	$1,157,448

Source: Building value is from HAZUS-MH. Estimated flood loss is 25 percent of total value.* Added in 2016, analysis based on import of DFIRM into HAZUS 3.1 Enhanced Quick Look

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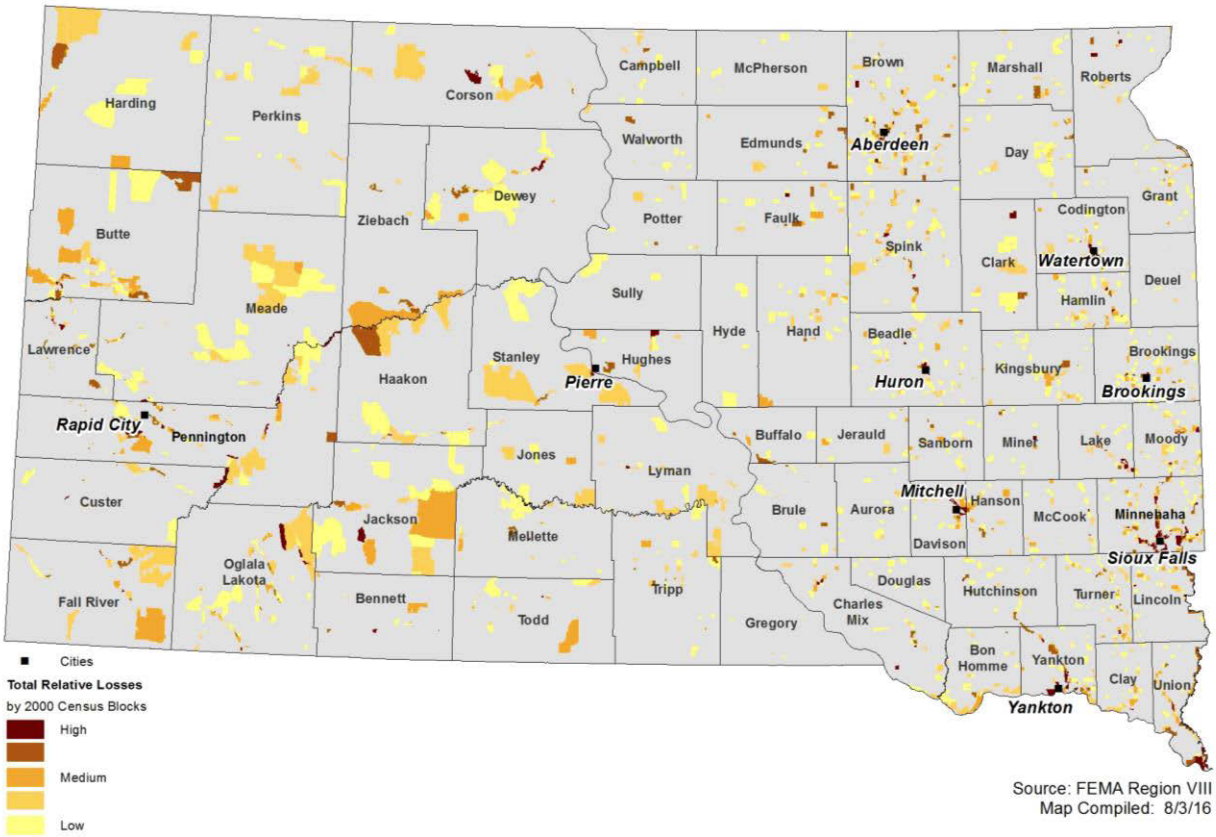
In 2009-2010 FEMA conducted a Hazus Flood Average Annualized Loss (AAL) study which was performed for the entire continental United States using the MR4 release of Hazus-MH. The analysis was performed at the county level using Level 1 methodology with national datasets. FEMA subsequently revised the study as the initial AAL costs appeared to over-estimate the average annual loss potential in most areas. The revised results were obtained from FEMA Region VIII during the 2013 update to the

HIRA and compared with the previous 1% annual chance Hazus analysis included from the 2010 update. As of mid-2016 an updated study was not available. AAL total losses for the state are estimated to be $45,996,000 based on this study. FEMA staff indicated that this loss estimate could be high. Based on updated NCDC data (see the flood hazard profile) alone AAL is $15.5 M, and about $1M based on NFIP claims data. The 1% annual chance total losses associated with the AAL study are $817,993,000. Based on the previous HAZUS Level 1 studies done in the 2010 plan (including buildings, contents and economic loss) the 1% annual chance $1.7 billion in flood losses for the state. It was determined that the existing level 1 HAZUS for the 1% annual chance flood (100-year) was still valid. Based on FEMA staff recommendations the AAL loss data is being used for relative risk comparisons only, and is illustrated on a loss by census block basis in the following figure.

Figure 3-56 Hazus MH Flood Average Annualized Loss



Flood Insurance Claims Analysis

In addition to the HAZUS-MH flood runs and local plans, the state analyzed National Flood Insurance Program (NFIP) flood-loss data to determine areas of South Dakota with the greatest flood risk. South Dakota flood-loss information was obtained from FEMA's "NFIP Policy and Claims Report" for South Dakota, which documents losses from 1978. This section was updated based on information obtained from FEMA through SD OEM in mid-2016.

There are several limitations to analyzing flood risk entirely on this data, including:

- Only losses to participating NFIP communities are represented,
- Communities joined the NFIP at various times since 1978,
- The number of flood insurance policies in effect may not include all structures at risk to flooding, and
- Some of the historical loss areas have been mitigated with property buyouts.

Despite these limitations, the data depict a pattern of historical flood losses in the state. The greatest losses have been in Codington, Lincoln, and Union counties. Table 3-46 shows the details of the 10 South Dakota counties with the greatest historical dollar losses. Union County was not within the top ten list in the 2010 plan update, but is now number three behind Codington and Lincoln Counties. Codington remains the leader in terms of overall dollars paid. Codington's polices, however, decreased from 835 in 2010 to 704 in 2012 to 524 in 2016. Since 2012, Lincoln County has increased dollars paid about $4 million, but decreased current policies by 35. Other notable changes include Minnehaha's decrease in dollars paid by about $2.5 million and over 1,000 less policies than it had in 2012. South Dakota's State NFIP coordinator explained the policy count decrease as partly related to the historic Missouri River flood of 2011, which caused a spike in policies. Union County, for example, went from 570 to almost 1,300 policies in 2011. Since then, people have opted to cancel their policies. Another large decrease could occur in 2018; the City of Sioux Falls had their levee system certified by the Corps of Engineers which will result in 1,600 structures no longer being required to have flood insurance when mapping becomes effective in 2017. NFIP policy summary statistics from FEMA for Region VIII states show a consistent trend towards a decrease in policies in each state.

Table 3-46 Top 10 Counties for Flood Insurance Dollars Paid (Historical), 1978 - 2016

County	Dollars Paid ($ Historical)	Flood Claims	Current Policies	Coverage ($)
Codington	$5,749,018	425	524	$97,426,900
Lincoln	$5,233,428	177	1,336	$389,092,500
Union	$5,076,498	420	403	$119,134,300
Hamlin	$4,201,281	347	57	$12,326,900
Day	$4,011,874	252	31	$4,943,600
Brown	$3,283,454	483	277	$51,238,300
Stanley	$2,555,204	113	125	$31,329,800
Lake	$1,419,607	152	169	$30,609,500
Spink	$921,480	69	36	$6,109,500
Minnehaha	$906,393	132	132	$24,017,700

Source: FEMA, NFIP Insurance Report, 2016

Information about flood insurance losses and policies for all South Dakota counties is in Appendix 3C. Based on this data the average annual insured losses are about $1 million.

Repetitive Loss Analysis

A high priority in South Dakota and nationwide is the reduction of losses to repetitive loss structures. These structures strain the National Flood Insurance Fund. They increase the NFIP's annual losses and

the need for borrowing and, more importantly, they drain resources needed to prepare for catastrophic events. The NFIP defines a repetitive loss property as "any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period, since 1978. At least two of the claims must be more than 10-days apart."

Table 3-47 illustrates the number and location (county) of South Dakota's 177 repetitive loss properties. Codington, Hamlin and Day counties are the top three by repetitive loss dollars paid. The numbers from the 2007, 2010, and 2012 plans have been preserved to show changes in the past 9 years. Note the increase in repetitive loss claims for several counties, likely due to the 2011 floods and to second homes. The State does not buyout second homes. Multiple buyouts in Day County are in process. Two new counties were added to this list since 2012: Lincoln and Union. However due to mitigation efforts repetitive loss property counts overall have decreased by four properties.

Table 3-47 NFIP Policies and Repetitive Loss Summary by County

County*	2007 # of RL Properties**	2010 # of RL Properties	2012 # of RL Properties	2016 # of RL Properties	Difference 2016-2012	2007 # of RL Claims	2010 # of RL Claims	2012 # of RL Claims	2016 # of RL Claims	2010 RL Dollars Paid ($ Historical)	2012 RL Dollars Paid ($ Historical)	2016 RL Dollars Paid ($ Historical)
Beadle	0	1	2	1	-1	0	3	6	3	43,389	116,289	72,899
Brookings			3	4	1			7	9		96,691	103,500
Brown	7	10	14	13	-1	14	21	29	27	162,871	206,324	198,798
Butte			1	1	0			2	2		6,593	6,593
Charles Mix	0	1	1	1	0	0	2	3	3	156,344	181,763	227,915
Clark	1	2	2	2	0	2	4	5	5	78,954	117,455	117,454
Clay			1	1	0			2	2		4,881	4,880
Codington	33	33	39	32	-7	74	72	95	80	1,427,850	1,872,695	1,552,284
Davison	1	1	1	1	0	2	2	2	2	17,207	17,207	17,206
Day	8	9	21	19	-2	16	18	43	41	359,057	1,186,524	1,125,151
Grant	2	2	2	4	2	4	5	5	10	44,453	30,943	107,408
Hamlin	4	4	41	38	-3	9	9	90	86	185,508	1,599,878	1,474,551
Hanson			1	1	0			2	2		5,771	5,770
Hughes	2	2	4	4	0	4	4	8	8	36,385	75,263	75,262
Lake	3	3	3	2	-1	6	6	6	4	81,511	81,511	61,511
Lincoln				6	6				13			2,690,957
Marshall			2	2	0			6	6		23,766	23,765
McCook			1	1	0			2	2		4,431	4,431
Meade			1	2	1			2	5		15,788	28,626
Minnehaha	10	10	17	17	0	21	21	41	42	94,423	266,517	300,464
Moody	3	3	7	7	0	7	8	19	19	81,815	180,728	180,727
Pennington			2	1	-1			4	2		17,331	5,261
Roberts			4	5	1	5		8	10		99,611	142,522
Spink			8	8	0			19	19		446,931	446,931

County*	2007 # of RL Properties**	2010 # of RL Properties	2012 # of RL Properties	2016 # of RL Properties	Difference 2016-2012	2007 # of RL Claims	2010 # of RL Claims	2012 # of RL Claims	2016 # of RL Claims	2010 RL Dollars Paid ($ Historical)	2012 RL Dollars Paid ($ Historical)	2016 RL Dollars Paid ($ Historical)
Turner			1	1	0			2	2		28,259	28,259
Union				1	1				2			70,098
Yankton			2	2	0			4	4		17,331	15,052
	74	81	181	177					410			**9,088,288**

Source: South Dakota Emergency Management, FEMA's "NFIP Insurance Report," 2016
*County includes policy and loss information for both incorporated and unincorporated areas
**Includes insured and uninsured properties

Severe Repetitive Loss Analysis

The Flood Insurance Reform Act of 2004 identified another category of repetitive loss, severe repetitive loss, and defined it as "a single family property (consisting of one-to-four residences) that is covered under flood insurance by the NFIP and has incurred flood-related damage for which four or more separate claims payments have been paid under flood insurance coverage with the amount of each claim payment exceeding $5,000 and with cumulative amount of such claims payments exceeding $20,000; or for which at least two separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property." In South Dakota, as of mid-2016, there are 10 properties that meet potentially meet this definition (6 of these were pending). Counties with these properties include Beadle, Clark, Coding, Day, and Hughes. In Codington County, one property experienced 9 losses and more than $566,000 in claims, and in Day County there are two properties that have over $100,000 in total claims each. According to the NFIP data none of these had been mitigated.

Future Vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their potential flood exposure as population and development increases by more than 15%.

Table 3-48 Flood Consequence Table

Category	Narrative
Impact on the Public	Impacts on people will change with characteristics of event (e.g., flash flood in a canyon, river flood on the plains, etc.); residents/ property owners without flood insurance may be impacted greater than those with coverage; residents may be displaced due to evacuation, damage, or inaccessibility to homes; persons within flood areas have the potential for direct contact with hazardous materials; potential for drowning or personal injury; increased potential for exposure to disease
Impact on the Economic Condition of the State	Local economy and finances adversely affected, possibly for an extended period of time depending on damage and length of investigation; potential for businesses to permanently close; localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services
Impact on the Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by flood; wetland impacts due to flooding can result in water quality impacts and wildlife habitat impacts; potential for hazardous materials impacts if a release

	occurs
Impact on Property, Facilities, and Infrastructure	Vulnerabilities to critical infrastructure, facilities and property in floodplain areas; High potential for flooded basements; foundation damage; transportation corridor (road, bridge, rail line) washouts; culvert damage
Impact on the Public Confidence in Government	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective
Impact on Responders	Need for evacuation support such as door-to-door notification and traffic management may increase responder risk; widespread flooding could stretch first responder personnel thin some areas; potential impacts to transportation corridors and communications lines may affect ability to effectively respond; possibility of responder injury or death; higher risk to responders in flash flood
Impact on Continuity of Operations	Damage to facilities/personnel in incident area may require temporary or permanent relocation of some operations
Cascading Hazards	Hazardous Materials Incidents, Dam Failure, Levee Failure

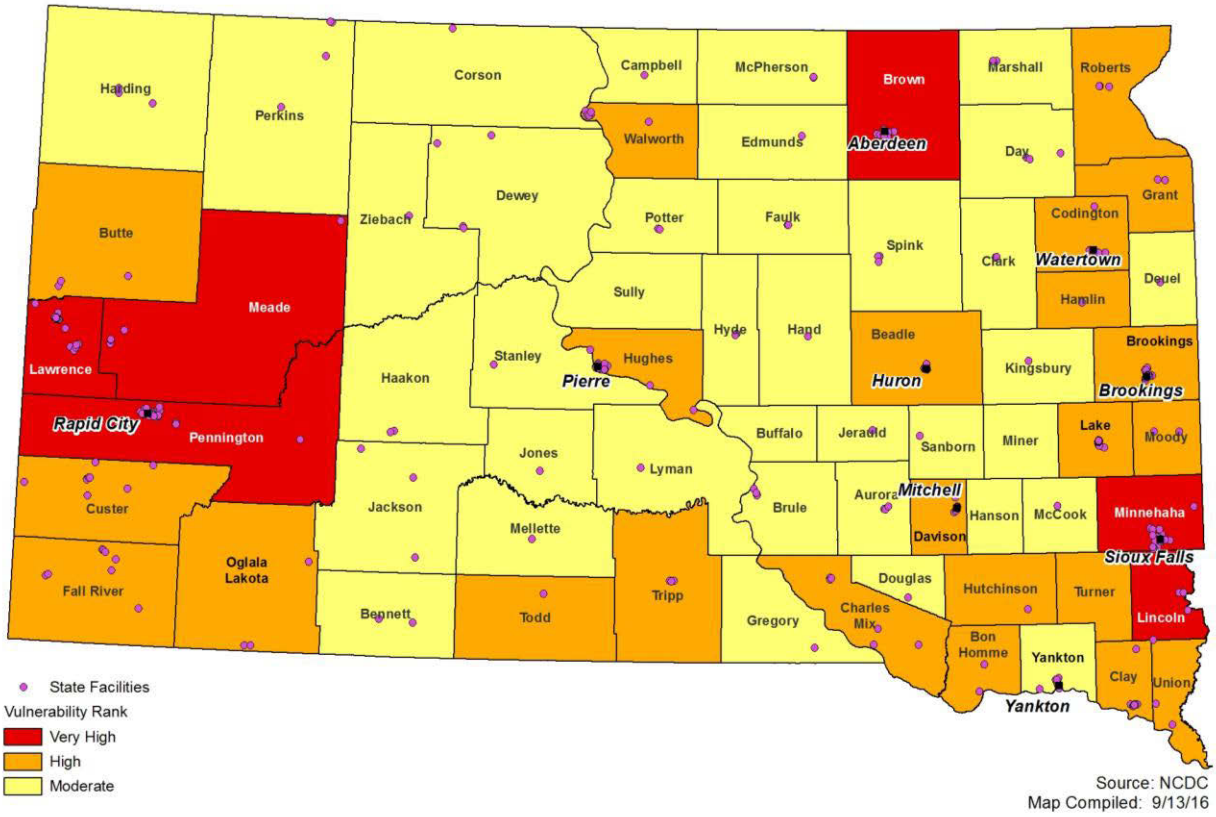
Summer Storms

Methodology

All counties in South Dakota are vulnerable to summer storms. To assess the relative vulnerability of each of South Dakota's counties to summer storms three factors were examined at the county level: prior events, building exposure, and population density. NCDC hail occurrence data was used for the prior events factor. The following tables and maps refer directly to hail vulnerability since lightning data is not as abundant or quantifiable. Ratings were applied to each factor and summed to obtain overall vulnerability scores for each county to allow comparison for greatest relative vulnerability.

This methodology assumes that the more developed areas, represented by greater building values and higher population densities, will generally have greater costs due to hail impacts. The more developed areas may have the capacity to absorb those costs more than the rural areas, so in terms of loss ratio (ratio of the losses to the total inventory in the county) the rural areas are potentially more vulnerable

Figure 3-57 Vulnerability of South Dakota Counties to Hail with State Facilities



Total Summer Storm Vulnerability and Estimate of Potential Loss

According to this methodology, while every county in South Dakota is vulnerable to hail; Brown, Lawrence, Lincoln, Meade, Minnehaha, and Oglala Lakota were rated as having a very high vulnerability.

The National Climatic Data Center data did not lend itself to county by county loss summaries, only a statewide summary. According to the National Climatic Data Center Storm Events database, there were 10,222 hail events in South Dakota between January 1996 and August 2016. Total property damage for these events is estimated at $160 million dollars. This suggests that South Dakota experiences $8.03 million in hail losses annually.

Between 1996 and 2016, NCDC recorded 114 separate lightning strikes, or almost six per year. Cumulatively, these storms caused five deaths, seventeen injuries, $2,171,200 in property damage and no in crop damage. Extrapolated into the future, the State of South Dakota can expect damaging lightning strikes annually; based on NCDC-recorded data, these strikes will cause one recorded injury every other year, and a lightning-caused fatality every four years. The average lightning strike in South Dakota causes $31,466 in property damage and no crop damage.

Table 3-49 Vulnerability of South Dakota Counties to Hail (ranked by vulnerability)

County	Prior Event Rating	Total Cumulative Damage ($)	Building Exposure Rating	Pop Density Rating	Vulnerability Rating
Pennington	10	$67,584,000	10	8	Very High
Minnehaha	4	$28,361,000	10	10	Very High
Lawrence	4	$5,763,000	8	8	Very High
Meade	7	$3,664,500	7	5	Very High
Brown	3	$0	8	8	Very High
Lincoln	1	$4,200,000	9	9	Very High
Codington	2	$0	8	8	High
Turner	2	$2,351,000	7	8	High
Davison	1	$5,050,000	7	9	High
Brookings	1	$9,430,000	8	8	High
Walworth	1	$0	8	8	High
Beadle	2	$125,000	7	7	High
Custer	5	$4,556,000	6	4	High
Clay	1	$250,000	6	8	High
Hughes	1	$0	7	7	High
Lake	1	$1,560,000	7	7	High
Tripp	2	$740,000	6	6	High
Oglala Lakota	3	$611,000	5	5	High
Charles Mix	2	$4,721,000	6	5	High
Bon Homme	2	$425,000	5	6	High
Roberts	1	$0	6	6	High
Hamlin	1	$0	5	6	High
Hutchinson	1	$7,391,000	6	5	High
Moody	1	$1,675,000	5	6	High
Grant	1	$0	5	6	High
Fall River	3	$2,713,250	5	3	High
Butte	2	$4,532,000	5	4	High
Todd	2	$573,000	4	5	High
Union	1	$581,000	5	5	High
Spink	2	$0	5	3	Moderate
Day	1	$0	5	4	Moderate
Marshall	1	$0	4	5	Moderate
Kingsbury	1	$3,506,000	5	4	Moderate
Deuel	1	$0	4	5	Moderate
Hand	3	$0	4	2	Moderate
Edmunds	2	$0	4	3	Moderate

County	Prior Event Rating	Total Cumulative Damage ($)	Building Exposure Rating	Pop Density Rating	Vulnerability Rating
Gregory	2	$4,960,000	4	3	Moderate
Clark	2	$0	4	3	Moderate
Brule	1	$7,140,000	4	4	Moderate
Hanson	1	$65,000	3	5	Moderate
Douglas	1	$1,275,000	3	5	Moderate
McPherson	1	$0	4	3	Moderate
Dewey	2	$0	3	2	Moderate
Lyman	2	$0	3	2	Moderate
Bennett	2	$2,087,000	2	3	Moderate
McCook	1	$135,000	3	3	Moderate
Aurora	1	$366,000	3	3	Moderate
Sanborn	1	$2,747,000	3	3	Moderate
Corson	3	$0	2	1	Moderate
Perkins	2	$2,051,000	3	1	Moderate
Haakon	2	$1,605,000	3	1	Moderate
Faulk	1	$0	3	2	Moderate
Stanley	1	$0	3	2	Moderate
Jerauld	1	$2,285,000	2	3	Moderate
Potter	1	$0	3	2	Moderate
Miner	1	$110,000	2	3	Moderate
Harding	3	$250,500	1	1	Moderate
Jackson	2	$1,127,500	2	1	Moderate
Campbell	1	$0	2	2	Moderate
Buffalo	1	$0	1	3	Moderate
Yankton	2	$17,270,000	1	1	Moderate
Sully	1	$0	2	1	Moderate
Hyde	1	$0	2	1	Moderate
Mellette	1	$170,500	1	1	Moderate
Jones	1	$0	1	1	Moderate
Ziebach	2	751,000	1	1	Moderate

South Dakota's data was obtained from the Risk Management Agency's indemnity reports for 2003 through 2016. The Risk Management Agency loss due to hail. The average annual crop damage statewide was $2,138,750 between January 1, 1996 and May 30, 2016 for Hail; total crop damage $42,775,000.

Future vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. As these counties continue to grow, their vulnerability to summer storms will increase as the exposure of population and property continues to grow. The agricultural industry will also continue to be vulnerable to hail. Counties that are particularly dependent economically on crops or livestock will have high vulnerability (see agricultural pests and diseases vulnerability discussion).

Table 3-50 Summer Storms Consequence Table

Category	Narrative
Impact on the Public	Exposure risks to motorists, outdoor workers, homeless persons, general public; risk to persons with energy dependent medical needs and pre-existing medical conditions.
Impact on the Economic Condition of the State	Potential loss of facilities or infrastructure function or accessibility and uninsured.
Impact on the Environment	Tree and vegetation damage, crop damage; animal impacts.
Impact on Property, Facilities, and Infrastructure	Buildings, equipment, and utility infrastructure are exposed to heavy hail, sometimes complicated by strong winds; transportation system impacts; possibility of roof damage; potential power loss and strain on energy systems.
Impact on the Public Confidence in Government	High expectations of government capabilities for reducing impact of hail events related to transportation.
Impact on Responders	Exposure risks; adverse working conditions.
Impact on Continuity of Operations	Potential loss of facilities or infrastructure function; potential loss of ability or accessibility to provide services; possible power interruption; transportation system impacts.
Cascading Hazards	Floods

Winter Storms

Methodology

All counties in South Dakota are vulnerable to winter storms. To assess the relative vulnerability of each of South Dakota's counties to winter storms, the state assigned ratings to three factors that were examined at the county level: prior events, building exposure, and population density. Ratings were applied to each factor and summed to obtain overall vulnerability scores for each county to allow comparison for greatest relative vulnerability. The methodology is further detailed in Appendix 3D South Dakota Vulnerability Methodology.

This methodology assumes that the more developed areas, represented by greater building values and higher population densities, will generally have greater costs for snow removal and functional downtime as a result of loss of utility services. The more developed areas may have the capacity to absorb those costs more than the rural areas, so in terms of loss ratio (ratio of the losses to the total inventory in the county) the rural areas are potentially more vulnerable. This is difficult to measure without good historical damage data, and is a limitation of this vulnerability assessment.

Total Winter Storm Vulnerability and Estimate of Potential Loss

According to this methodology, while every county in South Dakota is vulnerable to winter storms, Brookings, Brown, Davison, Lake, Lincoln, Meade, Minnehaha, and Pennington were rated with a "Very High" Vulnerability Ranking. .Figure 3-58 illustrates the vulnerability of South Dakota counties to winter storms, and Table 3-51 lists all the South Dakota counties ranked by total winter storm vulnerability along with their three vulnerability factor ratings.

Figure 3-58 illustrates the vulnerability of South Dakota counties to winter storms, and Table 3-51 lists all the South Dakota counties ranked by total winter storm vulnerability along with their three vulnerability factor ratings.

To estimate potential losses to winter storms, historic loss data was analyzed. The National Climatic Data Center data did not lend itself to county by county loss summaries, only a statewide summary. According to the National Climatic Data Center Storm Events database, there were 1,943 winter storms (snow and ice events) in South Dakota between January 1993 and August 2016, and 82 extreme cold events from January 1994 to October 2016. Total property damage for these events is estimated at $210.5 million dollars. This suggests that South Dakota experiences 59 winter storms and $6.4 million in winter storm losses annually, as well as 4.3 extreme cold events each year. 12 deaths and 127 injuries were attributed to these events. This suggests that South Dakota can expect approximately 1 death every other year and 6 injuries each year. Of these storms, 11 resulted in major disaster declarations. Based on the frequency of events, South Dakota averages one major disaster-level winter storm every year and a half.

If areas with the highest number of winter storm events are plotted on a map, it becomes immediately clear that some areas of the state have a higher occurrence rate than others. If counties with at least 50 events are plotted, the concentration of winter storms occurs primarily in the southeast corner of the state and in the Black Hills region, with a smaller occurrence in the far northeast corner. When these counties are narrowed to those with at least 60 events, the groupings of events is even clearer. This distribution

corresponds to the areas of highest elevation (the Black Hills region) and the areas with the greatest moisture content (the southeast corner of the state, where terrain is peppered with lakes and streams.

Figure 3-58 Vulnerability of South Dakota Counties to Winter Storms with State Facilities

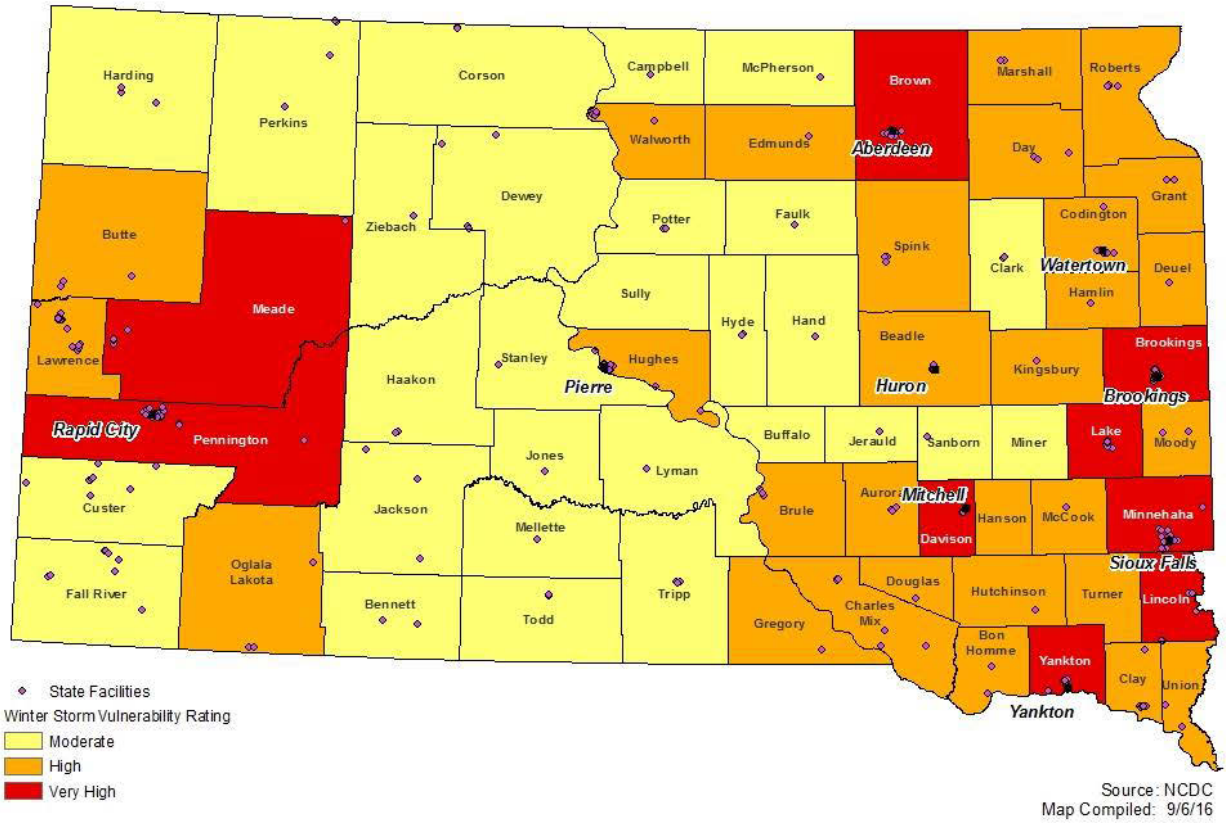


Figure 3-59 Vulnerability of South Dakota Counties to Winter Storms with Mitigation Projects

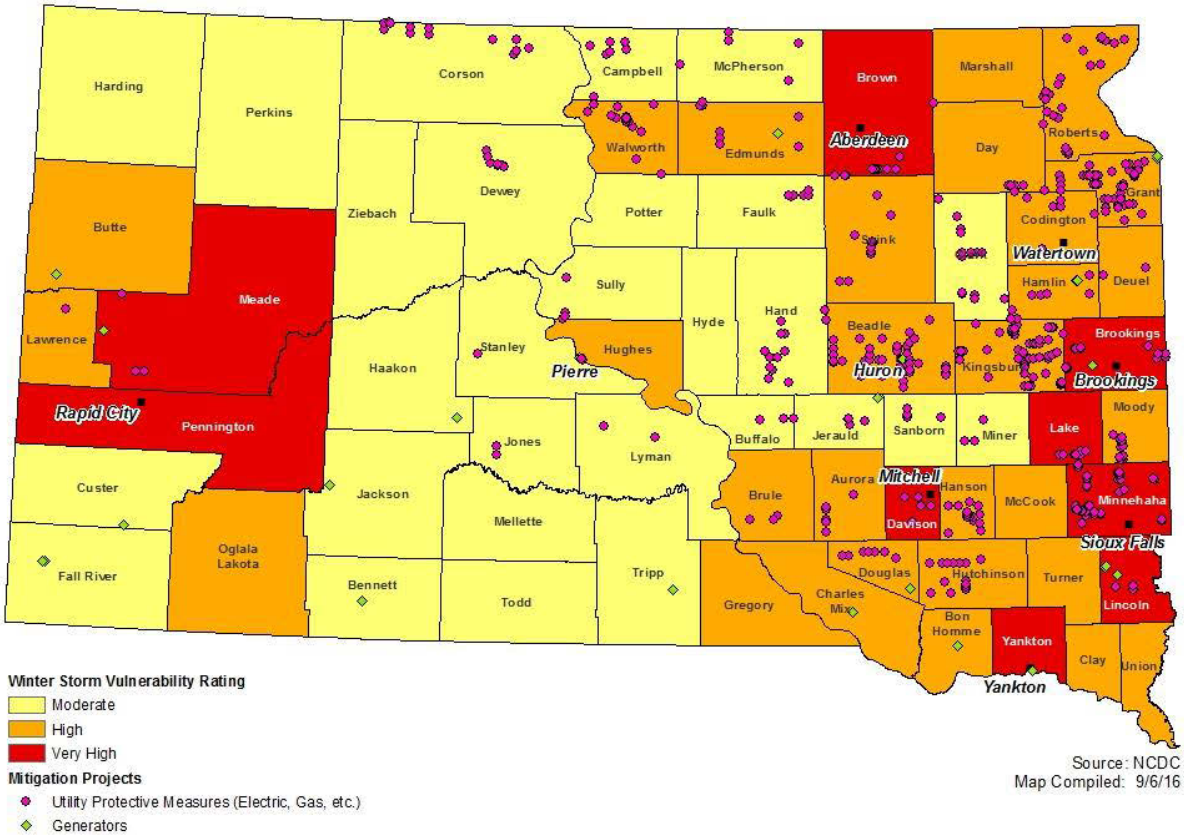


Table 3-51 Vulnerability of South Dakota Counties to Winter Storms (ranked by total vulnerability)

County	2016 Prior Event Rating	2016 Building Exposure rating.	2016 Pop Density Rating	Total rating	New rating
Brookings	7	**8**	8	23	Very High
Brown	5	**8**	8	21	Very High
Davison	6	**7**	9	22	Very High
Lake	7	**7**	7	21	Very High
Lincoln	6	**9**	9	24	Very High
Meade	10	**7**	5	22	Very High
Minnehaha	8	**10**	10	28	Very High
Pennington	4	**10**	8	22	Very High
Yankton	5	**8**	8	21	Very High
Aurora	6	**3**	3	12	High
Beadle	6	**7**	7	20	High

County	2016 Prior Event Rating	2016 Building Exposure rating.	2016 Pop Density Rating	Total rating	New rating
Bon Homme	6	**5**	6	17	High
Brule	6	**4**	4	14	High
Butte	6	**5**	4	15	High
Charles Mix	6	**6**	5	17	High
Clay	4	**6**	8	18	High
Codington	3	**8**	8	19	High
Day	5	**5**	4	14	High
Deuel	4	**4**	5	13	High
Douglas	5	**3**	5	13	High
Edmunds	5	**4**	3	12	High
Grant	5	**5**	6	16	High
Gregory	5	**4**	3	12	High
Hamlin	3	**5**	6	14	High
Hanson	6	**3**	5	14	High
Hughes	3	**7**	7	17	High
Hutchinson	7	**6**	5	18	High
Kingsbury	6	**5**	4	15	High
Lawrence	4	**8**	8	20	High
Marshall	6	**4**	5	15	High
McCook	7	**3**	3	13	High
Moody	6	**5**	6	17	High
Roberts	6	**6**	6	18	High
Oglala Lakota	3	**5**	5	13	High
Spink	5	**5**	3	13	High
Turner	7	**6**	6	19	High
Union	4	**7**	8	19	High
Walworth	3	**5**	5	13	High
Bennett	3	**2**	3	8	Moderate
Buffalo	2	**1**	3	6	Moderate
Campbell	2	**2**	2	6	Moderate
Clark	4	**4**	3	11	Moderate
Corson	3	**2**	1	6	Moderate
Custer	1	**6**	4	11	Moderate
Dewey	3	**3**	2	8	Moderate
Fall River	2	**5**	3	10	Moderate

County	2016 Prior Event Rating	2016 Building Exposure rating.	2016 Pop Density Rating	Total rating	New rating
Faulk	4	**3**	2	9	Moderate
Haakon	2	**3**	1	6	Moderate
Hand	4	**4**	2	10	Moderate
Harding	5	**1**	1	7	Moderate
Hyde	3	**2**	1	6	Moderate
Jackson	3	**2**	1	6	Moderate
Jerauld	6	**2**	3	11	Moderate
Jones	2	**1**	1	4	Moderate
Lyman	3	**3**	2	8	Moderate
McPherson	4	**4**	3	11	Moderate
Mellette	2	**1**	1	4	Moderate
Miner	6	**2**	3	11	Moderate
Perkins	4	**3**	1	8	Moderate
Potter	4	**3**	2	9	Moderate
Sanborn	4	**3**	3	10	Moderate
Stanley	2	**3**	2	7	Moderate
Sully	3	**2**	1	6	Moderate
Todd	2	**4**	5	11	Moderate
Tripp	3	**5**	3	11	Moderate
Ziebach	3	**1**	1	5	Moderate

South Dakota's data was obtained from the Risk Management Agency's indemnity reports for 2003 through 2016. The Risk Management Agency identifies several causes of loss related to extreme cold and winter weather, including cold winter, freeze, and frost. The Risk Management Agency has an "other" category that includes snow-lightning, etc., but it is not possible to determine which losses in this category resulted specifically from snow. South Dakota received $29,613,025 in indemnities from winter weather-related in 2015, $16,074,436 in 2014, $17,021,180 hazards in 2013, $4,304,101 in 2012, $4,521,931 in 2011, and $1,050,838 in 2010. This averages out to $12,097,585 in winter weather-related indemnities each year.

The USDA produced a "Cattle Death Loss" report in 2011 which detailed the number of cattle and calves lost to various causes (predator and non-predator) in each state in 2010. A total of 68,000 head of cattle and 90,000 calves died in South Dakota in 2010. 13.1% (890 head) of cattle losses and 36.8% (33,120 head) of calf losses were attributed to weather. The total value of the animals in South Dakota in 2010 was $1,133 per head for cattle and $381 per head for calves. Thus, the State's cattle industry suffered $13,627,090 in weather-related losses that year.

Future Vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. As these counties continue to grow, their vulnerability to winter storms will increase as the exposure of population and property continues to grow. The agricultural industry will also continue to be vulnerable to winter storms. Counties that are particularly dependent economically on crops or livestock will have high vulnerability.

Table 3-52 Winter Storms Consequence Summary

Category	Narrative
Impact on the Public	Exposure risks to motorists, outdoor workers, homeless persons, general public; risk to persons with energy dependent medical needs and pre-existing medical conditions.
Impact on the Economic Condition of the State	Potential loss of facilities or infrastructure function or accessibility and uninsured; impact to transportation sector and movement of goods, even if closures aren't in the state itself; lost revenue to decreased business patronage or inability of workers to reach employment locations.
Impact on the Environment	Tree and vegetation damage, crop damage; animal impacts.
Impact on Property, Facilities, and Infrastructure	Buildings, equipment, and utility infrastructure are exposed to heavy snow and ice, sometimes complicated by strong winds; transportation system impacts; possibility of roof collapse; potential power loss and strain on energy systems; frozen pipes; limited access to or ability to maintain operations of public transportation or access to transportation hubs.
Impact on the Public Confidence in Government	High expectations of government capabilities for reducing impact of snow and ice events related to transportation (roads, bridges, airports, rail); expectations for rapid power restoration.
Impact on Responders	Exposure risks; adverse working conditions; buried fire hydrants.
Impact on Continuity of Operations	Potential loss of facilities or infrastructure function; potential loss of ability or accessibility to provide services; possible power interruption; transportation system impacts.
Cascading Hazards	Floods

Wildfire

Methodology

The vulnerability analysis involved the use of GIS to quantify the population and buildings at risk within wildfire risk zones. The best available data for wildfire risk was the wildland- urban interface/intermix data from the SILVIS Lab at the University of Wisconsin–Madison mentioned previously in the wildfire hazard profile. The SILVIS data is classified into 13 categories, based on 2010 Census housing unit density and percent of vegetation in the area. In both interface and intermix communities, housing must meet or exceed a minimum density of one structure per 40 acres. Intermix communities are areas where housing and vegetation intermingle and vegetation exceeds 50 percent. Interface communities are areas with housing in the vicinity of contiguous vegetation, have less than 50 percent vegetation, and are within 1.5 miles of an area that exceeds 1,325 acres and are more than 75 percent vegetated. For the purposes of this plan these areas were further classified into High, Moderate, and Low risk threat zones as follows:

High Risk Threat Zone (areas of various housing unit density within areas of high vegetation)

- High Density Intermix
- Medium Density Intermix
- High Density Interface

Moderate Risk Threat Zone (areas of lower housing unit density within areas of high vegetation)

- Medium Density Interface
- Low Density Intermix

Low Risk Threat Zone (either no vegetation, or no housing density)

- Low Density Interface
- High Density No Vegetation
- Medium Density No Vegetation
- Wildland Intermix
- Uninhabited Vegetation
- Uninhabited No Vegetation
- Low Density No Vegetation
- Wildland No Vegetation

The SILVIS Census Blocks that met the High or Moderate Risk Threat Zone definitions above were selected within GIS and are represented on Figure 3-17. The total population and number of housing units within each zone was summarized by county, based on 2010 Census Block data included in the SILVIS data set. The results are shown in Table 3-53. The analysis shows 212,659 person and 98,378 housing units exposed in the high and moderate threat zones. Pennington County has the highest building and population exposure by far compared to the other counties, followed by Lawrence, Meade, Hughes, Custer and Butte. To estimate losses an exposure analysis was used based on applying an average home

value for each county (based on 2010 Census median home value) multiplied by the number of housing units at risk. For the purposes of estimating potential loss, the total replacement value is used as well as an estimate of contents (based on HAZUS occupancy class content estimate standards), as catastrophic fires tend to result in total loss of the structure. The total property exposed based on this methodology is $6 Billion in structures and $18 Billion including structure and contents. It is very unlikely that a wildfire would result in loss of all the structures potentially at risk within a given county, but the results provide an indication of where the highest losses from a fire in the Interface or Intermix areas could occur.

Table 3-53 WUI Exposure

County	Total Population	Total Housing Units	2010 Census Median Home Value ($)	2010 Medium Home Value*Housing Units ($)	Contents Replacement Value ($)	Total Replacement Value ($)
Aurora	-	-	-	-	-	-
Beadle	138	82	83,400	6,838,800	3,419,400	10,258,200
Bennett	1,669	597	60,200	35,929,818	17,964,909	53,894,727
Bon Homme	851	506	67,700	34,256,200	17,128,100	51,384,300
Brookings	494	282	138,300	39,000,600	19,500,300	58,500,900
Brown	125	71	115,700	8,214,700	4,107,350	12,322,050
Brule	2,262	1,091	87,300	95,221,556	47,610,778	142,832,335
Buffalo	1,071	299	67,500	20,182,500	10,091,250	30,273,750
Butte	7,335	3,333	114,300	380,927,373	190,463,687	571,391,060
Campbell	748	554	40,600	22,492,400	11,246,200	33,738,600
Charles Mix	376	199	67,700	13,472,300	6,736,150	20,208,450
Clark	197	104	64,500	6,708,000	3,354,000	10,062,000
Clay	100	54	116,900	6,312,600	3,156,300	9,468,900
Codington	828	361	131,000	47,291,000	23,645,500	70,936,500
Corson	2,054	741	45,900	34,011,900	17,005,950	51,017,850
Custer	6,340	3,578	160,700	574,984,600	287,492,300	862,476,900
Davison	661	277	108,800	30,137,600	15,068,800	45,206,400
Day	742	894	64,800	57,919,128	28,959,564	86,878,692
Deuel	444	193	87,200	16,812,339	8,406,170	25,218,509
Dewey	3,284	1,187	56,900	67,540,300	33,770,150	101,310,450
Douglas	10	4	58,300	233,200	116,600	349,800
Edmunds	618	324	70,300	22,777,200	11,388,600	34,165,800
Fall River	5,264	3,174	86,800	275,503,200	137,751,600	413,254,800
Faulk	788	485	51,300	24,880,500	12,440,250	37,320,750
Grant	233	121	99,800	12,123,280	6,061,640	18,184,920
Gregory	2,278	1,407	56,100	78,921,613	39,460,807	118,382,420
Haakon	1,013	558	74,800	41,738,400	20,869,200	62,607,600
Hamlin	173	76	83,700	6,361,200	3,180,600	9,541,800
Hand	98	72	74,900	5,392,800	2,696,400	8,089,200

County	Total Population	Total Housing Units	2010 Census Median Home Value ($)	2010 Medium Home Value*Housing Units ($)	Contents Replacement Value ($)	Total Replacement Value ($)
Hanson	77	24	87,300	2,095,200	1,047,600	3,142,800
Harding	385	261	67,000	17,487,000	8,743,500	26,230,500
Hughes	14,059	6,485	133,200	863,839,923	431,919,962	1,295,759,885
Hutchinson	22	14	68,700	961,800	480,900	1,442,700
Hyde	776	385	66,600	25,641,000	12,820,500	38,461,500
Jackson	1,791	660	54,600	36,036,000	18,018,000	54,054,000
Jerauld	71	43	62,200	2,674,600	1,337,300	4,011,900
Jones	629	373	75,000	27,975,000	13,987,500	41,962,500
Kingsbury	82	59	70,300	4,147,700	2,073,850	6,221,550
Lake	203	80	108,800	8,704,000	4,352,000	13,056,000
Lawrence	20,958	11,355	155,100	1,761,160,500	880,580,250	2,641,740,750
Lincoln	101	53	169,700	8,994,100	4,497,050	13,491,150
Lyman	2,280	1,034	64,900	67,106,600	33,553,300	100,659,900
Marshall	205	472	81,700	38,562,400	19,281,200	57,843,600
McCook	50	19	91,900	1,746,100	873,050	2,619,150
McPherson	824	653	45,100	29,450,300	14,725,150	44,175,450
Meade	20,512	9,013	145,800	1,314,095,400	657,047,700	1,971,143,100
Mellette	1,200	465	49,800	23,157,000	11,578,500	34,735,500
Miner	-	-	-	-	-	-
Minnehaha	899	329	144,900	47,672,100	23,836,050	71,508,150
Moody	66	26	102,800	2,672,800	1,336,400	4,009,200
Oglala Lakota	8,334	2,054	18,600	38,204,400	19,102,200	57,306,600
Pennington	78,815	34,905	149,700	5,225,253,054	2,612,626,527	7,837,879,581
Perkins	19	11	50,800	558,800	279,400	838,200
Potter	502	516	55,600	28,681,869	14,340,935	43,022,804
Roberts	964	415	73,200	30,378,000	15,189,000	45,567,000
Sanborn	104	52	62,700	3,260,400	1,630,200	4,890,600
Spink	119	53	62,700	3,323,100	1,661,550	4,984,650
Stanley	2,161	995	113,700	113,131,500	56,565,750	169,697,250
Sully	153	88	72,200	6,353,600	3,176,800	9,530,400
Todd	5,898	1,862	53,800	100,175,600	50,087,800	150,263,400
Tripp	1,313	707	69,400	49,093,265	24,546,633	73,639,898
Turner	47	18	85,600	1,540,800	770,400	2,311,200
Union	2,392	1,059	132,200	140,049,081	70,024,541	210,073,622
Walworth	4,528	2,525	62,500	157,791,465	78,895,732	236,687,197
Yankton	752	388	115,500	44,814,000	22,407,000	67,221,000
Ziebach	1,176	304	62,200	18,903,145	9,451,573	28,354,718

County	Total Population	Total Housing Units	2010 Census Median Home Value ($)	2010 Medium Home Value*Housing Units ($)	Contents Replacement Value ($)	Total Replacement Value ($)
Totals	**212,659**	**98,378**	**5,337,800**	**12,205,037,912**	**6,105,938,356**	**18,317,815,068**

Forest fires are of longer duration due to the heavy fuels and resistance to control efforts. Fires in forested areas have the potential to do significant damage to homes and property. These fires generally cost more to suppress than prairie fires. Prairie fires tend to stress local response resources and can quickly damage livestock grazing areas. Damage to agricultural resources is very dependent on when the fire occurs, with the early season March and April fires easier to recover from. Research yielded little information on agricultural losses due to wildfire. RMA indemnities data for 2010, 2011, and 2012 only showed fire-related losses in 2011. Total fire-related indemnities for that year were $126,230. While historic loss data was limited on agricultural losses from fires this information may be collected in future updates from sources that might include the Farm Services Agency, Risk Management Agency, State Department of Agriculture, or South Dakota State University.

Additional vulnerability data was obtained from individual county Community Wildfire Protection Plans (CWPPs) where possible. A digital copy of Fall River County's CWPP was reviewed for the 2013 plan update. The Fall River County CWPP identified 3,918 structures in the County with an assessed value of roughly $388 million as of 2008. 523 structures with an assessed value of $6.8 million were located in the Black Hills Forest Fire Protection District. Lawrence, Meade, Pennington, and Perkins counties also provided digital CWPPs but did not provide estimates of assessed property values at risk to wildfire. Other jurisdictions that have completed CWPPs in the State include Butte, Custer, and Stanley counties and Rapid City. South Dakota's numerous recreational, historical, archaeological, and paleontological sites are also vulnerable to wildfire events.

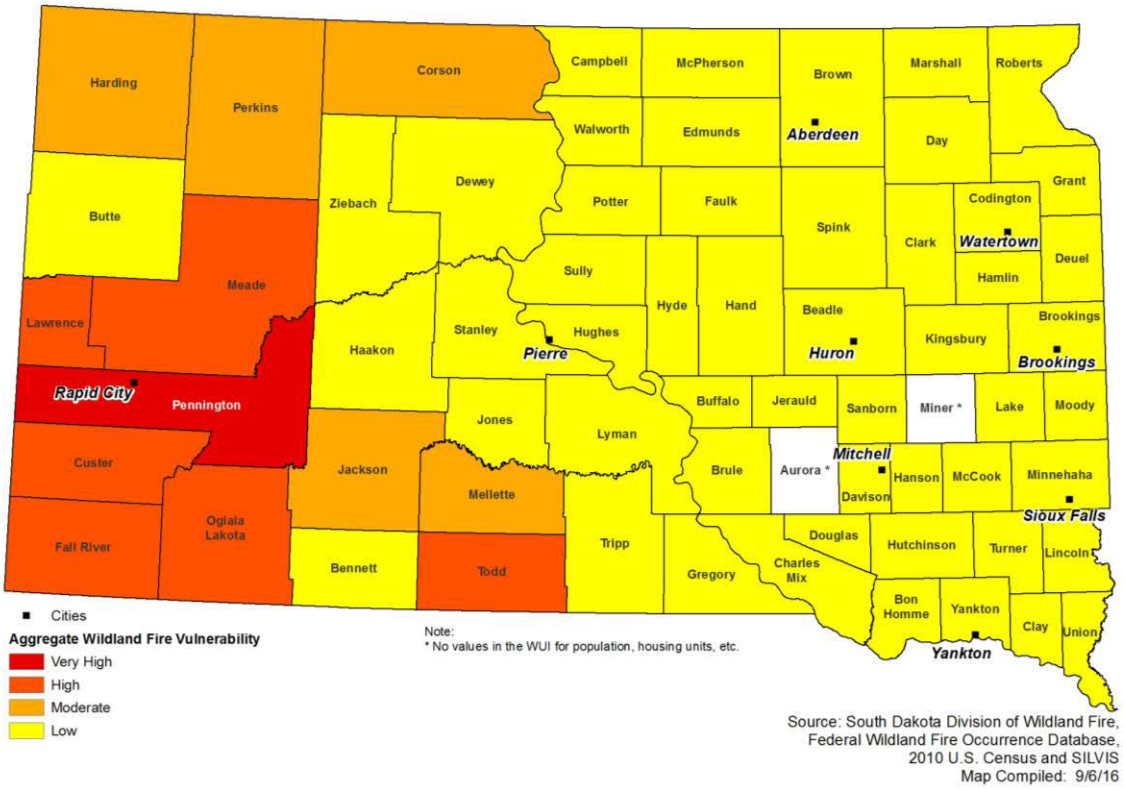
The following information on wildfire vulnerability is from the South Dakota Drought Mitigation Plan:

National Drought Mitigation Center Impact Records

South Dakota has experienced a variety of impacts from previous droughts. Wildfire impacts reported to the National Drought Mitigation Center (NDMC) can include enacting or easing burning restrictions, fireworks bans, increased fire risk, occurrence of fire (number of acres burned, number of wildland fires compared to average, people displaced, etc.), state of emergency during periods of high fire danger, closure of roads or land due to fire occurrence or risk, and expenses to state and county governments of paying firefighters overtime and paying equipment (helicopter) costs.[6] Figure 52 shows the number of these impacts reported for each county from January 1, 1980 to April 13, 2015. The greatest number of drought impacts reported to the NDMC occur in counties in West River, namely Lawrence and Pennington counties. The higher number of impacts in these counties can at least partially be attributed to the presence of a major population center (Rapid City) near the WUI.

[6] Sources: National Drought Mitigation Center

Figure 3-60 Number of Reported Wildfire Impacts by County (Drought Impact Reporter 1980-2015)



The Normalized Difference Vegetation Index (NVDI) is used to measure vegetation conditions and generator Greenness maps to analyze potential fire risk. Examples from 2006 and 2012 are shown below.

Figure 3-61 NDVI Greenness Map for August 31, 2006

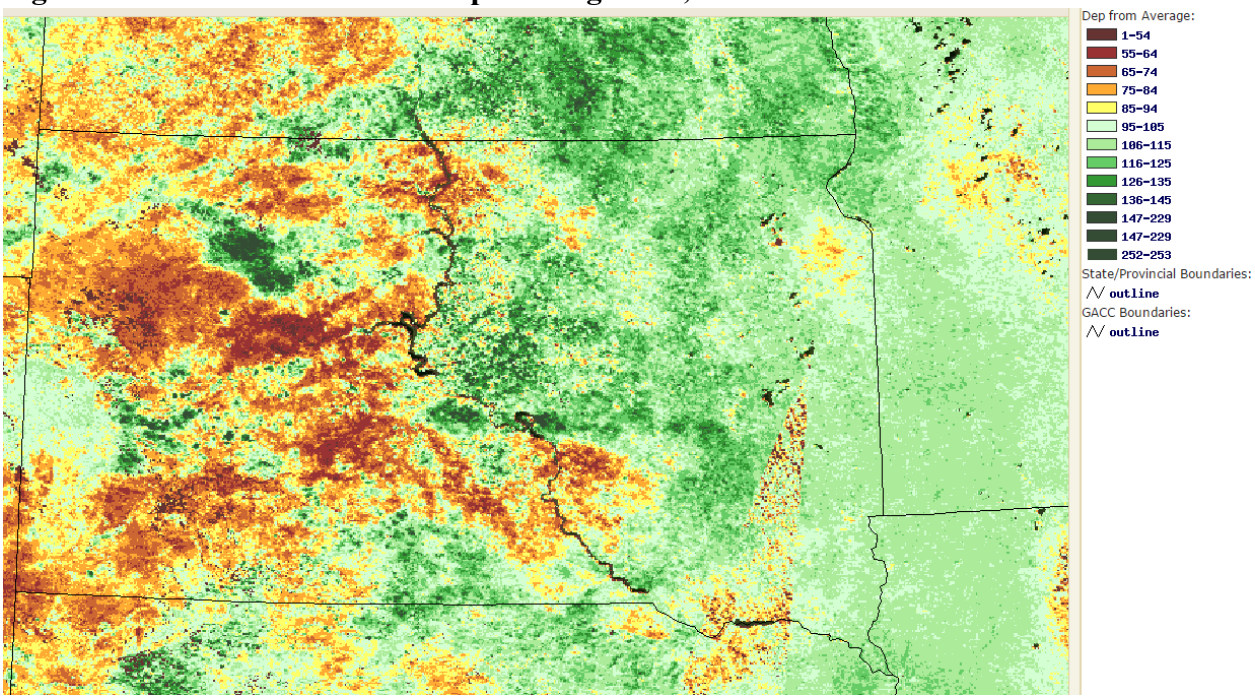
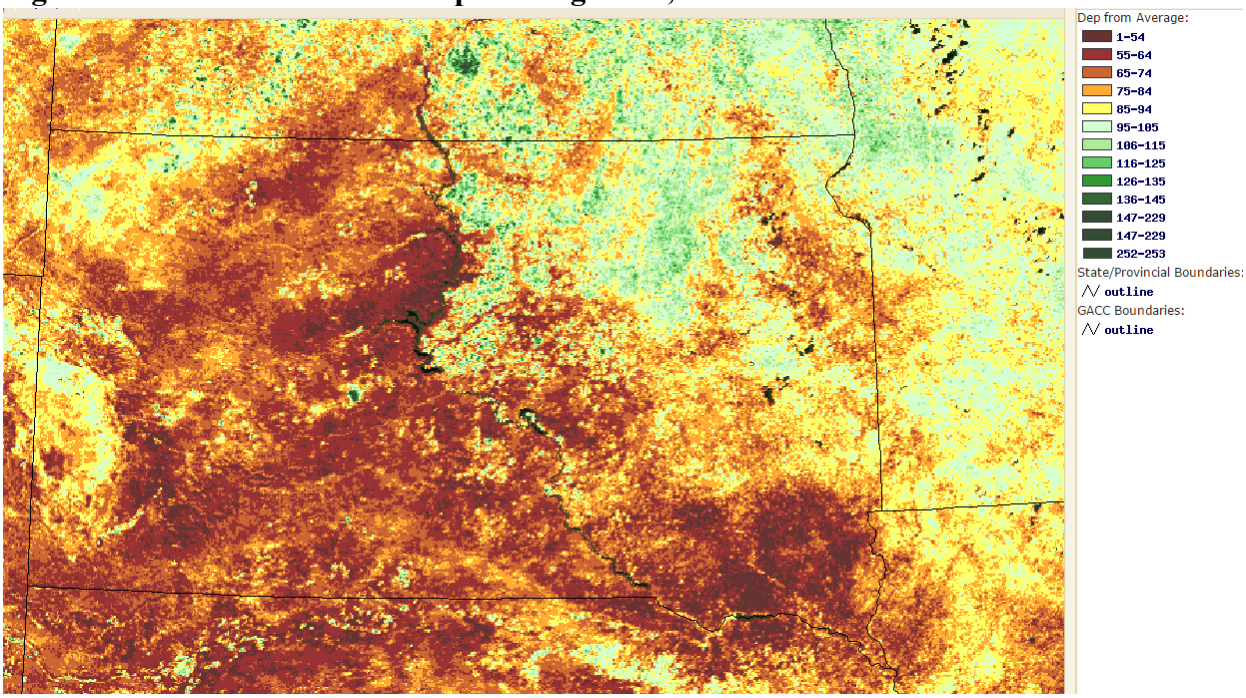


Figure 3-62 NDVI Greenness Map for August 31, 2012



Factors that Impact Vulnerability to Wildfires

South Dakota's vulnerability to wildfires is influenced by several factors. These factors may not affect all counties in the same way.

Fuels

Fuels in South Dakota are generally conducive to high rates of spread, represented by National Fire Danger Rating System fuel models "G", "L," "K," and "C." Grass predominates in the broad valley bottoms. Ponderosa Pine grows on all aspects, and extensive pure forests of Ponderosa grow in the Black Hills. Mixed grass and timber stands occur in many areas depending on aspect.

Fuel density in the Black Hills is greater today than in the past. When wildfires occur in high density fuel loads under dry, warm, and windy conditions, they will frequently develop into uncontrollable crown fires that destroy the forest and any homes within it. Fuel loading is lightest in the southern Black Hills and heaviest in the northern Black Hills.

Topography

The Black Hills are an outcropping of the Rocky Mountains, lying in an ellipse 100 miles long and 50 miles wide along the State's western edge. In the Black Hills, terrain varies from broad, open valleys; rolling topography; mountainous terrain up to 7,242 feet in elevation; and steep, narrow canyons. The topography in the Black Hills is conducive to rapid wildfire spread. Fires spread faster on steep slopes as the heat from the flames is closer to the next fuel source.

Beetle and Insect Infestation

Mountain pine beetle infestations often coincide with drought, which weakens trees. When the beetle population is very low only stressed or weakened trees, such as those struck by lightning, are colonized. However, approximately every ten years the beetle population increases and the beetles begin colonizing healthy as well as stressed trees. These circumstances have been common throughout the Black Hills and have allowed a mountain pine beetle infestation to become epidemic. The Custer State Park area around Harney Peak, and the Norbeck Wildlife Preserve adjacent to Mount Rushmore has extremely high fuel loading due to Mountain Pine Beetle outbreaks. The South Dakota Department of Agriculture (SDDA) reported in 2012 that the mountain pine beetle population had reached epidemic proportions. SDDA published a Black Hills Regional Mountain Pine Beetle Strategy (2012) which proposed mitigation strategies for reducing the population to endemic levels over the course of several years.

Climate and Weather

During the summer months, temperatures are often in the 90s with relative humidity in the teens. Temperatures may climb into the low 100s, though this is rare in South Dakota. The average annual precipitation is approximately 17.5 inches, with the East River generally receiving more precipitation than West River. Some of this precipitation is associated with thunderstorms that bring lightning during the fire season.

Lightning fires burn more acreage than human-caused fires, in part, because 1) multiple lightning fire ignitions often occur at the same time; 2) lightning fires can occur throughout the protection area, while most human-caused fires occur in accessible areas; 3) people often detect and report human-caused fires quickly due to their proximity to inhabited areas; and 4) lightning producing thunderstorms typically occur during the hottest portion of the fire season, while many human-caused fires start during spring or fall. When combined with drought, these conditions can create devastating wildfires.

Climate change may also affect wildfire risk and magnitude in the future. Longer, hotter summers deplete moisture in soils and vegetation. Beetles and other insects favor drier conditions that weaken trees and make them more vulnerable to infestation. Water supply for vegetation and fire suppression may also decrease as snowpack melts earlier and precipitation declines and evaporates more rapidly. Climate change is also believed to increase the severity of thunderstorms, leading to more lightning strikes that can ignite fires.[7]

Growth and Development Trends

Wildfires destroy hundreds of structures throughout the western United States every year. These fires can and will occur anywhere that humans and their development meet or intermix with wildland fuels. This wildland-urban interface fire problem exists in every state, including South Dakota, and worsens each year. People continue to develop residential properties in fire-prone environments, increasingly exposing themselves and their personal property to the risks of wildfire. An increase in population in the WUI also means more potential ignition sources. People may accidentally start forest or rangeland fires when using farming equipment, camping, or burning trash on their properties.

Estimating Potential Losses

Fire Response Expenditures

Drought can create conditions for more numerous and intense fires that quickly overwhelm local and state capacities for fire suppression. Generally, large wildfires make up a small portion of total fire occurrences in any given year but account for the greatest portion of suppression costs. Expenses can also be driven up by atypically large numbers of moderate or small fires that drain resources. Table 3-54 summarizes South Dakota's fire suppression costs from 1994 to 2014. State fire suppression costs have been $2,226,539 annually between 1994-2014 Between 1974 and 2012, (see the fire management assistance declarations in Table 3-4). This averages $306,510 annually *per year* and does not include losses to structures, forests, utilities, etc. Note that the amount of financial support was not known for every event. Within that 20-year time period, the highest suppression costs occurred in 2002, 2006, 2007, and 2012; each of these years coincided with a drought. The fire suppression costs for these years was orders of magnitude greater than that of wet years, such as 2010. In addition, in response to the drought year 2006, the South Dakota Legislature passed a law that was enacted to allow the use of the State Fire Suppression Fund to pay for responding and managing large wildfire activity in the prairie regions of the state. This can drive up fire fund expenditures in future years. (Source, SDCL 41-20A-8.)

Table 3-54 State Fire Suppression Costs by Year, 1994-2014

Year	State Fire Suppression Costs
2014	$454,641
2013	$893,262
2012*	$8,493,171
2011	$1,789,511
2010	$801,405
2009	$525,343
2008	$938,134
2007*	$7,686,640
2006*	$6,026,422
2005	$2,127,925
2004	$1,009,829
2003	$1,599,697
2002*	$9,444,193
2001	$2,025,028
2000	$1,510,648
1999	$191,441
1998	$135,301
1997	$149,239
1996	$307,694
1995	$258,766
1994	$389,033
Total	**$46,757,325**

Source: South Dakota Department of Agriculture, 2015;
*Drought year

Exposure, Values at Risk, and Number and Magnitude of Reported Fires by County

An analysis of areas of the State that are most vulnerable to the impacts wildfire was conducted as an estimate of where wildfire would have the highest consequences. This analysis was completed based on several factors including the total replacement value of homes in the WUI, the total population in the WUI, the number of housing units, average annual number of historical fires at least 1,000 acres in size, and average annual burned acreage. The fire occurrence data used in the analysis ranges over

a 56-year time span between 1959 and 2015. Each of these factors was assigned a numerical value between 1 and 4, with 1 representing low values and 4 representing high values. The score for each factor was added to obtain a total numerical value for each county. The highest scores indicated the highest vulnerability to wildfire. Pennington County has the highest overall vulnerability to wildfire. Lawrence, Meade, Custer, Fall River, Oglala Lakota, and Todd counties were ranked in the second highest vulnerability. Harding, Perkins, Corson, Jackson, and Mellette counties were ranked at moderate vulnerability. The data indicated that Aurora and Miner counties did not have any population or structures at risk in the WUI, nor did they have any previous fire occurrences.

Figure 3-63 Aggregate Wildland Fire Vulnerability

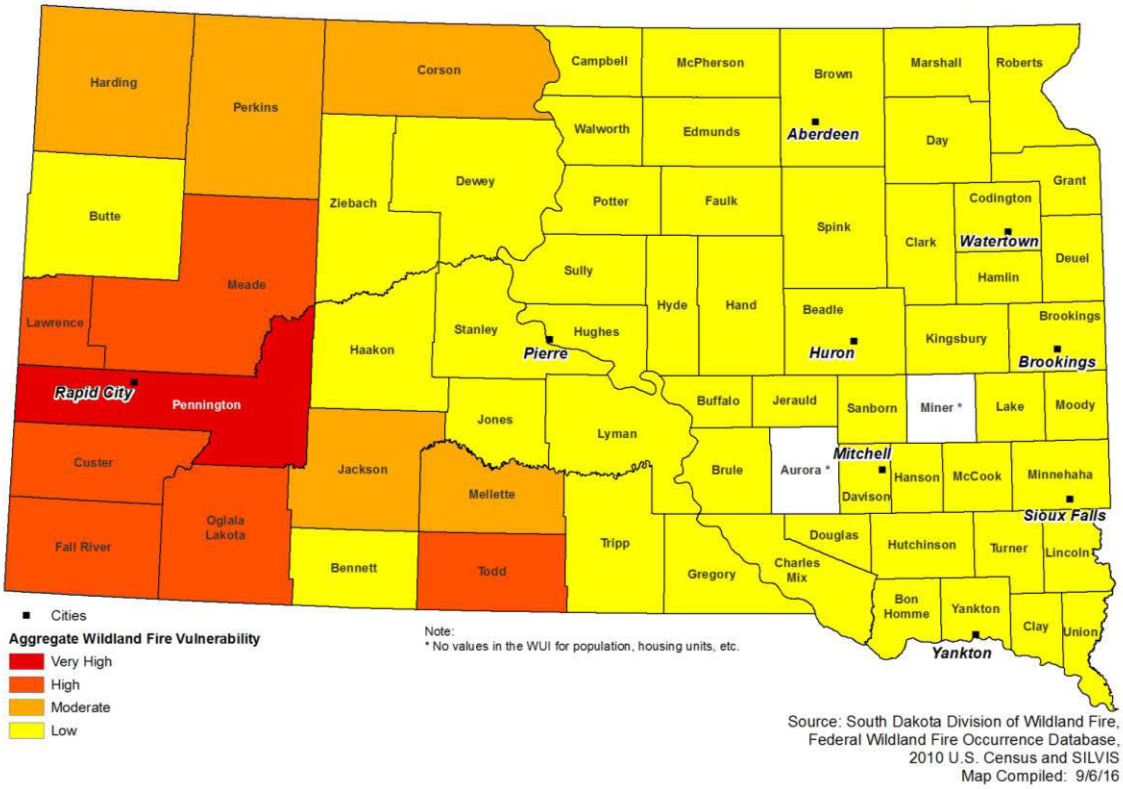


Table 3-55 State Fire Suppression Costs by Year, 1994-2014

Year	State Fire Suppression Costs
2014	$454,641
2013	$893,262
2012*	$8,493,171
2011	$1,789,511
2010	$801,405
2009	$525,343

Year	State Fire Suppression Costs
2008	$938,134
2007*	$7,686,640
2006*	$6,026,422
2005	$2,127,925
2004	$1,009,829
2003	$1,599,697
2002*	$9,444,193
2001	$2,025,028
2000	$1,510,648
1999	$191,441
1998	$135,301
1997	$149,239
1996	$307,694
1995	$258,766
1994	$389,033
Total	**$46,757,325**

Source: South Dakota Department of Agriculture, 2015;
*Drought year

Summary of Economic Impacts

Based on the previous analysis over the past 21 years, fire suppression costs in South Dakota have averaged $2,226,539 million annually. Drought has undoubtedly exacerbated the magnitude and frequency of fires in the State, leading to higher fire suppression costs. Wildfire also impacts tourism revenue and can have a more direct impact on visitation than drought alone. This is discussed in more detail in the Tourism Sector.

Future Vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%.

Table 3-56 Wildfire Consequence Table

Category	Narrative
Impact on the Public	Staff, recreationists, campers, property owners in remote areas or the wildland urban interface areas, and persons with breathing difficulties may at risk to injury or death; secondary impacts may negatively affect water quality and downstream water users.
Impact on the Economic Condition of the State	Potential loss of facilities or infrastructure; potential impact to tourism and land development activities depending on severity of the fire season and location of fire events. Depending on nature of area where fire occurs, many home based businesses will be impacted due to evacuation, lack of utility service, or through destruction of property. State fire suppression and management costs average $2M annually.
Impact on the Environment	Significant impact related to loss of forest or grasslands, impacts to water quality; erosion and sedimentation may affect critical infrastructure and natural waterways. Loss of ground vegetation may encourage landslides, mudslides, or other geologic movement of land. Dead or damaged trees are at risk of falling.
Impact on Property, Facilities, and Infrastructure	Vulnerabilities in wildland urban interface areas include critical infrastructure, facilities, properties, equipment, vehicles, and communications and utility infrastructure.
Impact on the Public Confidence in Government	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective. Coordinated warning and evacuation is essential.
Impact on Responders	Exposure exists to response personnel performing routine duties when event occurs; fire event - related duties may cause significant danger to response personnel including evacuation, suppression, law enforcement, and damage assessment. Local, state and federal fire management personnel involved in firefighting at risk to injury and death.
Impact on Continuity of Operations	Potential loss of facilities or infrastructure function or accessibility or ability to provide services. Power interruption is likely if not adequately equipped with backup generation.
Cascading Hazards	Landslides, Floods

Drought

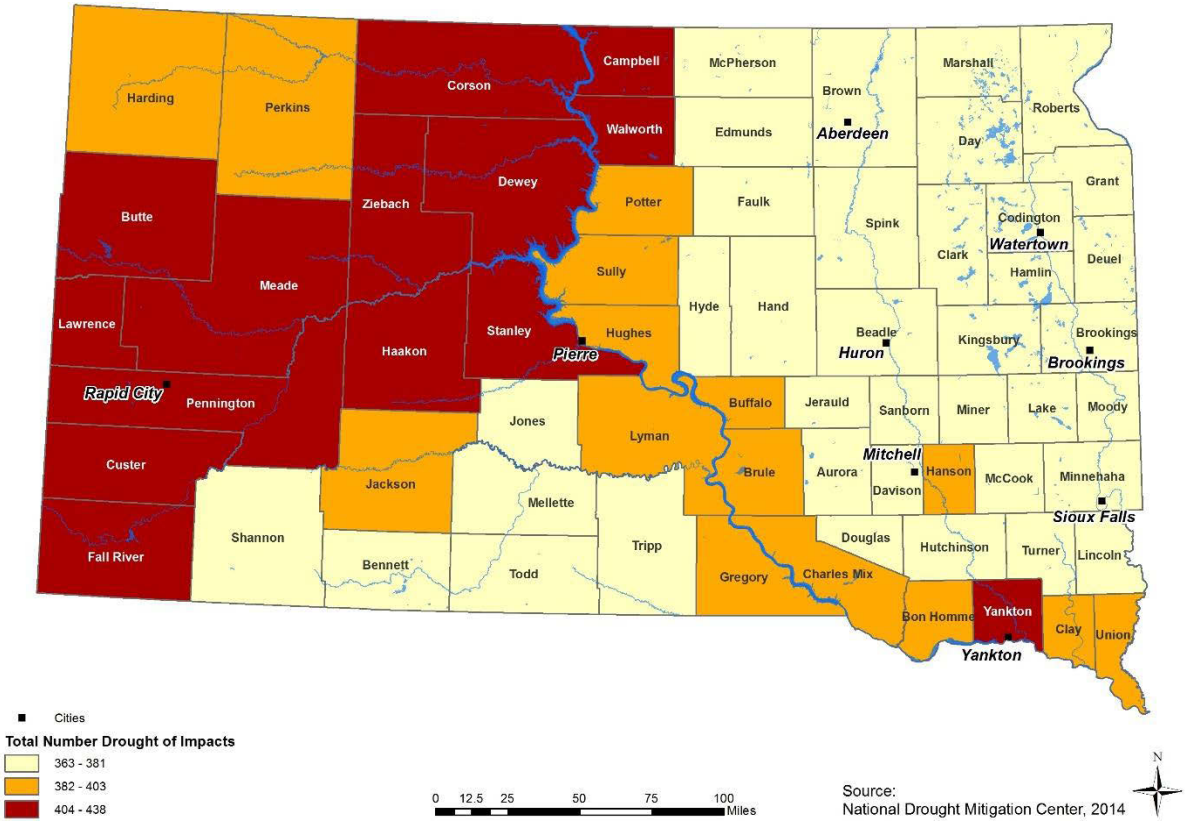
As discussed in the profile, the entire State of South Dakota is vulnerable to drought, but in different ways. A summary of impacts from the Drought Impact Reporter completed during the development of the South Dakota Drought Mitigation Plan indicates that all counties are vulnerable.

Figure 3 shows reported total drought impacts for all South Dakota counties from 1980 to May 2015 in the following impact categories:

- Agriculture
- Business & Industry
- Energy
- Fire
- Plants & Wildlife
- Relief, Response & Restrictions
- Society & Public Health
- Tourism & Recreation
- Water Supply & Quality

Those counties shown with a higher number of impacts include recreational areas such as the "Great Lakes" Missouri River corridor and Black Hills Regions. In addition to agriculture impacts these areas could suffer from lowered lakes levels impacting boating and fishing activities and associated revenue.

Figure 3-64 Drought Impact Reporter for South Dakota (January 1980-May 2015)



Source: South Dakota Drought Mitigation Plan 2015

Drought takes a particularly heavy toll on agriculture due to crop losses from lack of moisture. Farmers often protect themselves from the effects of drought by insuring all or a portion of their crop against drought losses. This is done through multi-peril crop insurance, which is underwritten by The Risk Management Agency. The Risk Management Agency, part of the USDA, maintains a database of crop insurance claims. Table 3-57 shows the crop losses due to drought in one of the most recent and severe periods of statewide drought, which occurred in 2002. Drought-related crop losses that year totaled $294,625,661. Data for 2002 is compared to that of 2012, both significantly dry years in South Dakota. In 2012 drought-related crop losses totaled $838,876,036, nearly three times as much as the losses in 2002. The drought in 2012 was particularly worse for some counties, notably Hutchinson, Bon Homme, Charles Mix, Lincoln, and McCook. In 2013, the drought-related crop losses totaled $232,648,444. In 2014, the losses totaled $20,902,831 and in 2015, the losses totaled $48,005,987.

Table 3-57 South Dakota Crop Loss Due to Drought: 2002 and 2012

County	2002 Indemnities ($)	2012 Indemnities ($)
Aurora	9,981,468	20,312,297
Beadle	16,888,079	15,920,978
Bennett	3,031,438	2,547,781
Bon Homme	6,868,510	53,074,783
Brookings	387,848	4,652,860
Brown	3,492,269	3,867,983
Brule	10,078,871	11,189,445
Buffalo	3,093,701	5,442,786
Butte	570,113	568,080
Campbell	3,352,881	1,639,784
Charles Mix	14,953,511	52,741,118
Clark	4,452,317	6,613,557
Clay	1,250,351	37,583,767
Codington	1,394,286	6,544,813
Corson	4,422,324	3,837,987
Custer	309,970	617,713
Davison	7,885,578	25,309,304
Day	979,621	2,046,009
Deuel	371,275	3,268,970
Dewey	2,612,684	1,718,676
Douglas	5,463,319	32,805,118
Edmunds	5,121,562	3,333,600
Fall River	319,562	1,659,373
Faulk	3,245,911	3,244,005
Grant	218,744	3,096,120
Gregory	4,700,874	13,427,341
Haakon	4,439,525	5,317,145
Hamlin	347,794	5,296,778
Hand	12,896,771	7,447,056
Hanson	3,298,202	26,245,752
Harding	3,402,141	1,841,929
Hughes	9,941,061	5,915,209
Hutchinson	9,758,512	94,572,548
Hyde	8,411,019	4,555,116
Jackson	2,546,546	1,749,899
Jerauld	5,164,721	3,543,515
Jones	2,182,334	2,660,595
Kingsbury	4,896,508	4,912,931
Lake	1,167,346	3,646,413
Lawrence	19,545	83,794
Lincoln	139,801	55,931,547
Lyman	9,304,102	9,970,739

County	2002 Indemnities ($)	2012 Indemnities ($)
McCook	624,002	45,295,473
McPherson	4,624,314	4,338,115
Marshall	476,464	1,021,099
Meade	4,288,087	4,512,961
Mellette	1,187,891	1,459,244
Miner	3,799,930	6,899,052
Minnehaha	576,527	29,759,062
Moody	311,254	2,742,224
Oglala Lakota	1,188,991	1,157,968
Pennington	3,261,621	3,339,429
Perkins	8,077,696	3,292,653
Potter	13,821,626	3,994,871
Roberts	80,479	880,552
Sanborn	3,651,509	5,650,254
Spink	10,169,572	8,827,121
Stanley	4,749,540	1,951,946
Sully	18,609,676	8,206,428
Todd	978,776	1,580,025
Tripp	7,241,518	15,736,702
Turner	1,379,258	56,652,120
Union	131,241	28,868,718
Walworth	5,895,543	781,254
Yankton	3,498,560	49,536,920
Ziebach	2,638,591	1,636,631
Total	**294,625,661**	**838,876,036**

Source: Risk Management Agency Cause of Loss Historical Data Files

The South Dakota Drought Mitigation Plan analyzed agricultural areas of the State that are most vulnerable to the impacts of drought. The analysis was completed based on crop exposure as well as the crop loss data based on crop insurance payments. The drought-related crop insurance payments have been extrapolated to estimate damages to insurable crops that are not insured. This is based on the percent of insurable crops that are covered by crop insurance. Ninety-one percent of South Dakota's crops were insured in 2014. The crop exposure value from the 2012 Census of Agriculture is provided as the basis for the development of a loss ratio by county. The loss ratio is the average annualized losses divided by overall crop exposure. The higher the ratio the higher the vulnerability. Average annualized losses were obtained from Risk Management Agency historical crop indemnity data. The 2000-2014 indemnities related to drought were added together and then divided by 15 (for the 15-year time period from 2000 to 2014). Over the past 15 years, insured crop losses in South Dakota due to drought have averaged $189 million annually.[8]

[8] 2015 Risk Management Agency data

Table 3-58 provides the annualized estimated crop losses by county due to drought. Figure 3-65 displays this data in a statewide thematic map. The vulnerability rank is based on the calculated crop damage ratio. Figure 3-66 displays this information in a color-coded statewide map. The map indicates a trend of higher vulnerability in the southeastern counties as well as most counties located west of the Missouri River.

Table 3-58 Crop Vulnerability Analysis to Drought

County Name	Crop Exposure Value (2012 Census of Agriculture)	Drought-Related Crop Insurance Paid (2000-2014)	Crop Damages (extrapolated based on 91% insured in 2014)	Annualized Crop Damages	Crop Damage Ratio (%)	Vulnerability Rank*
Aurora	$68,196,000	$60,107,074	$66,051,730	$4,403,449	6%	Moderate
Beadle	$190,063,000	$92,111,439	$101,221,362	$6,748,091	4%	Moderate
Bennett	$22,270,000	$17,758,157	$19,514,458	$1,300,964	6%	Moderate
Bon Homme	$41,325,000	$73,489,666	$80,757,875	$5,383,858	13%	Very High
Brookings	$162,340,000	$14,051,951	$15,441,704	$1,029,447	1%	Low
Brown	$462,905,000	$68,329,209	$75,087,042	$5,005,803	1%	Low
Brule	$76,953,000	$59,487,913	$65,371,333	$4,358,089	6%	Moderate
Buffalo	$22,972,000	$20,227,215	$22,227,709	$1,481,847	6%	Moderate
Butte	$17,320,000	$3,737,033	$4,106,630	$273,775	2%	Low
Campbell	$62,126,000	$28,953,764	$31,817,323	$2,121,155	3%	Low
Charles Mix	$102,917,000	$111,016,981	$121,996,682	$8,133,112	8%	High
Clark	$159,568,000	$30,126,654	$33,106,213	$2,207,081	1%	Low
Clay	$79,678,000	$58,576,644	$64,369,939	$4,291,329	5%	Moderate
Codington	$108,293,000	$23,376,681	$25,688,661	$1,712,577	2%	Low
Corson	$59,621,000	$27,898,868	$30,658,096	$2,043,873	3%	Low
Custer	$2,871,000	$3,257,277	$3,579,425	$238,628	8%	High
Davison	$50,170,000	$57,768,651	$63,482,034	$4,232,136	8%	High
Day	$158,390,000	$18,397,556	$20,217,095	$1,347,806	1%	Low
Deuel	$93,232,000	$10,278,900	$11,295,495	$753,033	1%	Low
Dewey	$29,240,000	$18,302,602	$20,112,749	$1,340,850	5%	Moderate
Douglas	$41,558,000	$57,730,389	$63,439,988	$4,229,333	10%	Very High
Edmunds	$186,317,000	$66,231,491	$72,781,859	$4,852,124	3%	Low
Fall River	$6,474,000	$8,444,878	$9,280,086	$618,672	10%	Very High
Faulk	$156,409,000	$48,886,691	$53,721,639	$3,581,443	2%	Low
Grant	$135,881,000	$18,178,471	$19,976,341	$1,331,756	1%	Low
Gregory	$39,961,000	$34,859,827	$38,307,502	$2,553,833	6%	Moderate
Haakon	$33,129,000	$38,890,487	$42,736,799	$2,849,120	9%	High
Hamlin	$124,886,000	$12,122,384	$13,321,302	$888,087	1%	Low
Hand	$197,905,000	$60,871,887	$66,892,183	$4,459,479	2%	Low
Hanson	$67,135,000	$50,813,618	$55,839,141	$3,722,609	6%	Moderate

County Name	Crop Exposure Value (2012 Census of Agriculture)	Drought-Related Crop Insurance Paid (2000-2014)	Crop Damages (extrapolated based on 91% insured in 2014)	Annualized Crop Damages	Crop Damage Ratio (%)	Vulnerability Rank*
Harding	$17,114,000	$12,352,443	$13,574,113	$904,941	5%	Moderate
Hughes	$87,163,000	$51,862,163	$56,991,388	$3,799,426	4%	Moderate
Hutchinson	$71,342,000	$147,360,051	$161,934,122	$10,795,608	15%	Very High
Hyde	$63,078,000	$41,078,904	$45,141,652	$3,009,443	5%	Moderate
Jackson	$17,969,000	$16,808,952	$18,471,376	$1,231,425	7%	High
Jerauld	$62,010,000	$25,495,565	$28,017,104	$1,867,807	3%	Low
Jones	$40,121,000	$20,801,602	$22,858,903	$1,523,927	4%	Moderate
Kingsbury	$175,284,000	$36,624,897	$40,247,140	$2,683,143	2%	Low
Lake	$112,379,000	$10,578,149	$11,624,340	$774,956	1%	Low
Lawrence	$2,424,000	$279,496	$307,138	$20,476	1%	Low
Lincoln	$103,441,000	$79,528,376	$87,393,820	$5,826,255	6%	Moderate
Lyman	$95,031,000	$59,056,885	$64,897,676	$4,326,512	5%	Moderate
Marshall	$146,118,000	$14,962,187	$16,441,964	$1,096,131	1%	Low
McCook	$96,689,000	$65,847,210	$72,359,572	$4,823,971	5%	Moderate
McPherson	$84,627,000	$38,911,478	$42,759,866	$2,850,658	3%	Low
Meade	$25,425,000	$26,702,248	$29,343,130	$1,956,209	8%	High
Mellette	$13,929,000	$7,893,801	$8,674,507	$578,300	4%	Moderate
Miner	$74,947,000	$27,165,658	$29,852,371	$1,990,158	3%	Low
Minnehaha	$164,228,000	$39,826,268	$43,765,130	$2,917,675	2%	Low
Moody	$131,252,000	$8,304,554	$9,125,884	$608,392	0%	Low
Oglala Lakota	$8,720,000	$7,474,476	$8,213,710	$547,581	6%	Moderate
Pennington	$29,599,000	$19,390,759	$21,308,526	$1,420,568	5%	Moderate
Perkins	$43,281,000	$31,657,712	$34,788,695	$2,319,246	5%	Moderate
Potter	$140,531,000	$57,310,814	$62,978,916	$4,198,594	3%	Low
Roberts	$200,141,000	$16,253,489	$17,860,977	$1,190,732	1%	Low
Sanborn	$69,389,000	$25,796,275	$28,347,555	$1,889,837	3%	Low
Spink	$334,151,000	$59,735,881	$65,643,825	$4,376,255	1%	Low
Stanley	$40,815,000	$42,644,551	$46,862,143	$3,124,143	8%	High
Sully	$186,494,000	$100,036,938	$109,930,701	$7,328,713	4%	Moderate
Todd	$15,910,000	$6,432,324	$7,068,487	$471,232	3%	Low
Tripp	$86,671,000	$46,512,542	$51,112,684	$3,407,512	4%	Moderate
Turner	$100,867,000	$77,854,625	$85,554,533	$5,703,636	6%	Moderate
Union	$106,501,000	$46,118,750	$50,679,945	$3,378,663	3%	Low
Walworth	$89,049,000	$29,051,962	$31,925,233	$2,128,349	2%	Low
Yankton	$56,866,000	$66,978,827	$73,603,107	$4,906,874	9%	High
Ziebach	$19,261,000	$20,593,934	$22,630,696	$1,508,713	8%	High
Totals	**$6,072,922,000**	**$2,579,569,105**	**$2,834,691,324**	**$188,979,422**		

Source: Amec Foster Wheeler based on analysis of data from USDA Risk Management Agency; 2012 USDA Census of Agriculture

* Vulnerability ranking classification based on the following loss ratios: Low (0-3%), Moderate (4-6%), High (7-9%), Very High (10-15%)

Figure 3-65 Annualized Estimated Crop Economic Losses from Drought, by County 2000-2014

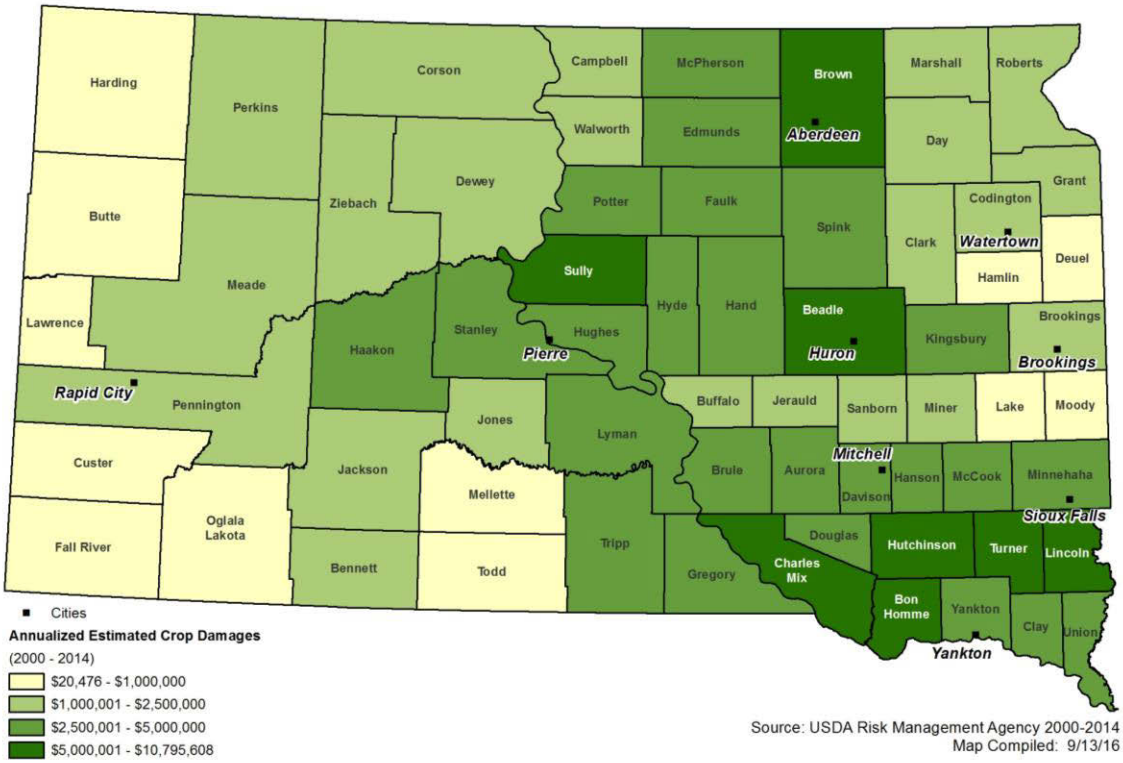
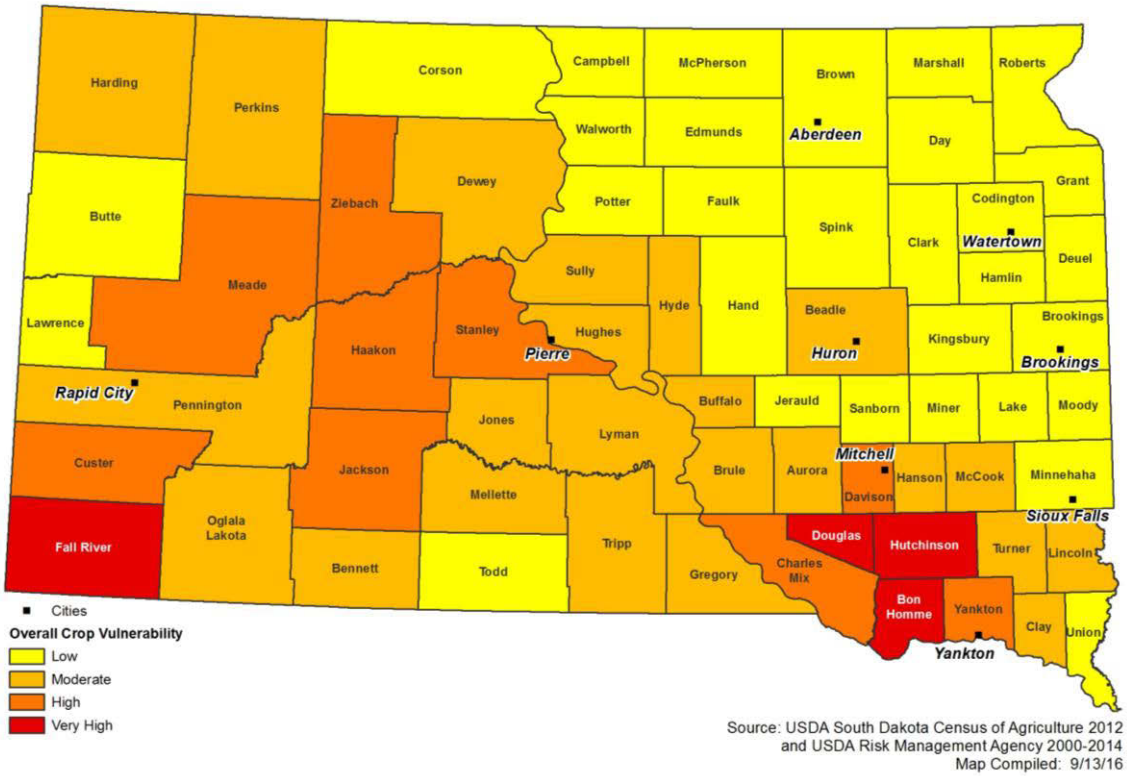


Figure 3-66 Crop Vulnerability Rank by County - 2000-2014



Future Vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. Based on the State Drought Mitigation Plan the availability of water supplies in some of these areas is becoming an issue as the population increases, particularly in Sioux Falls and other areas that depend on the Big Sioux River. Rapid City, in the Black Hills is also experiencing water availability challenges related to population growth that can be exacerbated during dry periods. In the western portion of the State, there is concern regarding the need of water for people and rangeland. Areas can best reduce their drought vulnerability by effectively planning for reliable future water supplies.

Table 3-59 Drought Consequence Table

Category	Narrative
Impact on the Public	Health impacts from low water quality; reduced air quality; increased risk of infectious diseases/contamination; water supply disruptions and reduced water quality could impact service delivery; air quality from blowing dust could have detrimental heath impacts.
Impact on the Economic Condition of the State	Agricultural economies are adversely affected if drought results in widespread loss of crop or yield reductions or livestock impacts. Agricultural supply and support industries can also be affected. Food costs increase due to higher costs or lack of production; reduced tourism and recreation revenue for activities reliant on precipitation (i.e. ski industry; summer water sport industries, fishing, hunting). Local economy and finances dependent on consistent water supply or precipitation (i.e. snow at ski areas) may be adversely affected for duration of drought.
Impact on the Environment	Disruptions in wildlife and habitat, including increased animal mortality; decreased land quality; low stream flows; increased water contamination. May cause disruptions in wildlife habitat, resulting in an increasing interface with people, or reducing numbers of animals if forage becomes too sparse. Land quality can be negatively impacted by overgrazing during drought. Water quality can become degraded to the point of causing localized fish kills. Low stream flows and higher water temperatures will have negative impacts on riparian habitats and aquatic species.
Impact on Property, Facilities, and Infrastructure	Infrastructure can be damaged by excessively dry expansive soil as it contracts; dams and ditches can experience structural damage due to decreased pore water pressure, damage caused by high sediment loads when pulling water from the bottom of reservoirs, and damage caused by debris flows and flooding following wildfires. Water treatment facilities may be stressed. Reduced hydroelectric power generation.
Impact on the Public Confidence in Government	Ability to respond and recover may be impaired if planning, response, and recovery not timely and effective.
Impact on Responders	Strain on water supply for responders; minor impacts; dust storms

	might require special equipment.
Impact on Continuity of Operations	Strain on water supply for operations and municipal services reliant on water. Slow onset and nature of drought makes it unlikely to have an impact on continuity of operations. Nature of hazard not expected to impact delivery of government services, except for moderate impact on water utilities. In extreme cases municipal water delivery may be interrupted. Ability to deliver recreational services may be impacted at the local level. Food supply and delivery could be disrupted, with an associated increase in food prices.
Cascading Hazards	Wildfire, Flood, expansive soil issues

Tornadoes

Methodology

All 66 counties in the state of South Dakota are vulnerable to tornado hazards. To refine and assess the relative vulnerability of each of South Dakota's counties to tornadoes, the state assigned ratings to four factors that were examined at the county level: prior events, building exposure, population density, and past tornado damage. Ratings were applied to each factor and summed to obtain overall vulnerability scores for each county to allow comparison for greatest relative vulnerability. The methodology is further detailed in Appendix 3D South Dakota Vulnerability Methodology.

Figure 3-67 Tornado Damage 1950-2016

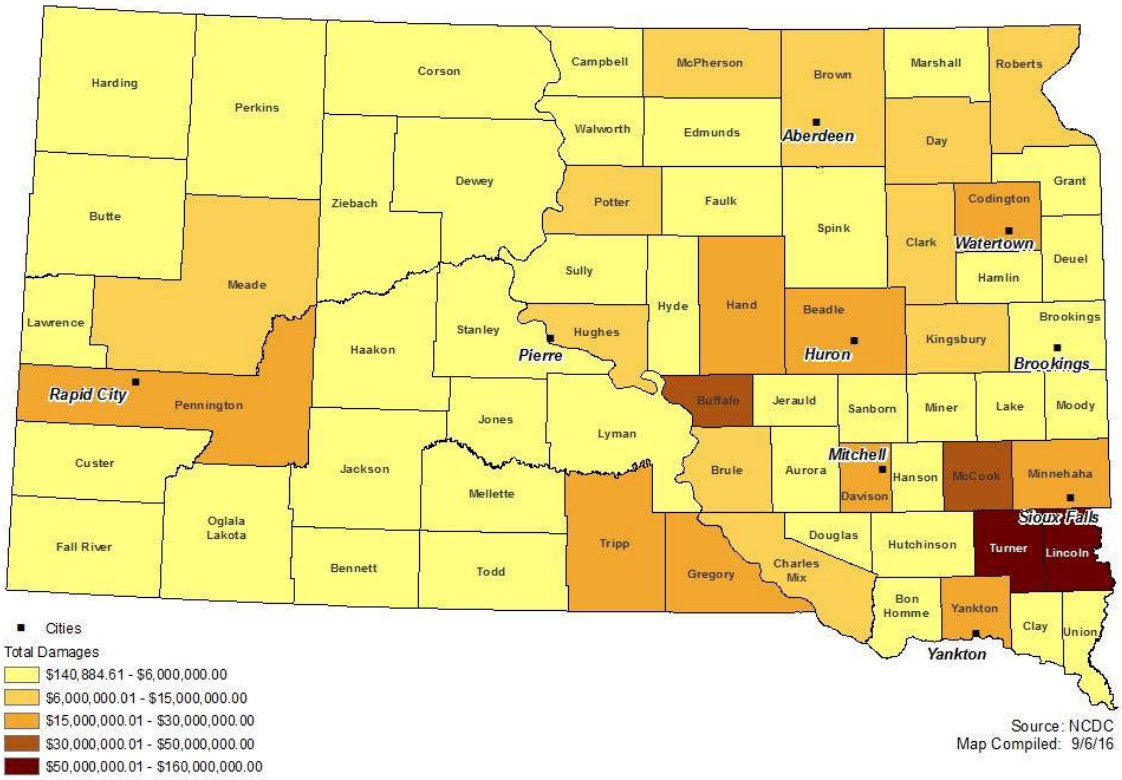


Figure 3-67 shows past tornado damage ratings for all South Dakota counties. A table that includes the corresponding values can be found in Appendix 3D Vulnerability Methodology.

Total Tornado Vulnerability and Estimate of Potential Loss

According to this methodology, while every South Dakota county is vulnerable to tornadoes, only Minnehaha and Lincoln Counties have a very high vulnerability for tornadoes with a Fujita rank of F1 or greater, or that caused damage or casualties. Lincoln is the only county with Very High rank for all tornadoes. Figure 3-68 illustrates the vulnerability of South Dakota counties to tornadoes, and Table 3-60 shows all the South Dakota counties ranked by total tornado vulnerability along with their four vulnerability factor ratings.

To provide additional insight into potential losses caused by tornadoes, historic loss data were also analyzed on a statewide scale. According to the National Climatic Data Center Storm Events database, there were 1,726 tornadoes in South Dakota between January 1950 and August 2016. Of those, 790 were rated as greater than F1. Total property damage for these events is estimated at $713 million in 2016 dollars. This suggests that South Dakota experiences 26 tornadoes and $10.8 million in losses each year. There were 18 deaths and 452 injuries in this time period, which averages out to approximately seven injuries each year. Of these storms, five resulted in major disaster declarations, with a total relief cost estimated at $160 million in 2016 dollars. This averages out to $31.711 million per major disaster. Based

on the frequency of events, South Dakota averages one major disaster-level tornado every 328 events or approximately every 12.4 years.

Based on Figure 3-68, tornadoes do not seem to concentrate in one particular area of the State. If the counties with at least 15 F1 or greater events are plotted on the map, the concentration remains in the southeast corner. The only outliers are Pennington, Meade, and Brown. As such, it is expected that the counties of Minnehaha, Lincoln, Turner, McCook, Yankton, Charles Mix, and Davison have higher vulnerabilities to tornados and associated losses than the other counties in the state, although Pennington, Beadle, and Brown Counties should all also be considered at high risk.

Figure 3-68 Tornado Vulnerability and State Facilities

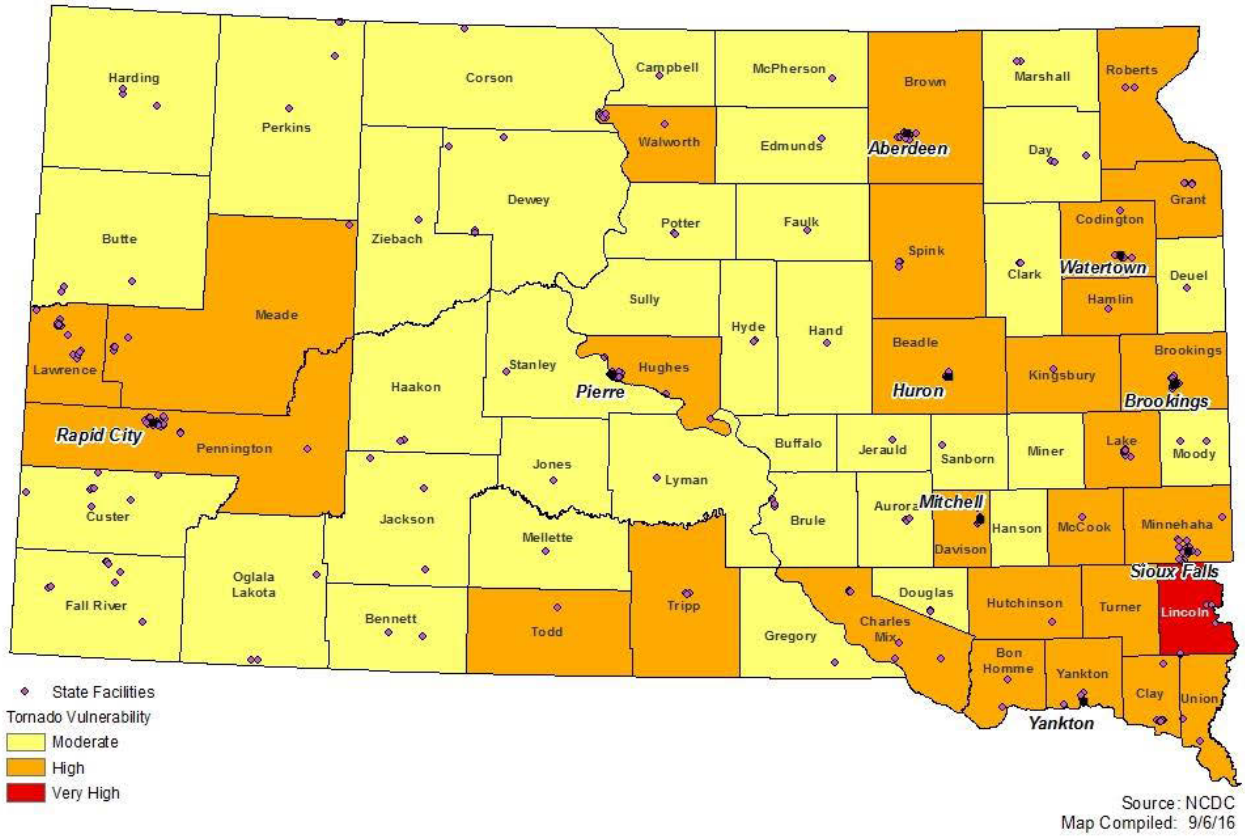


Figure 3-69 Tornado Vulnerability and Mitigation Projects

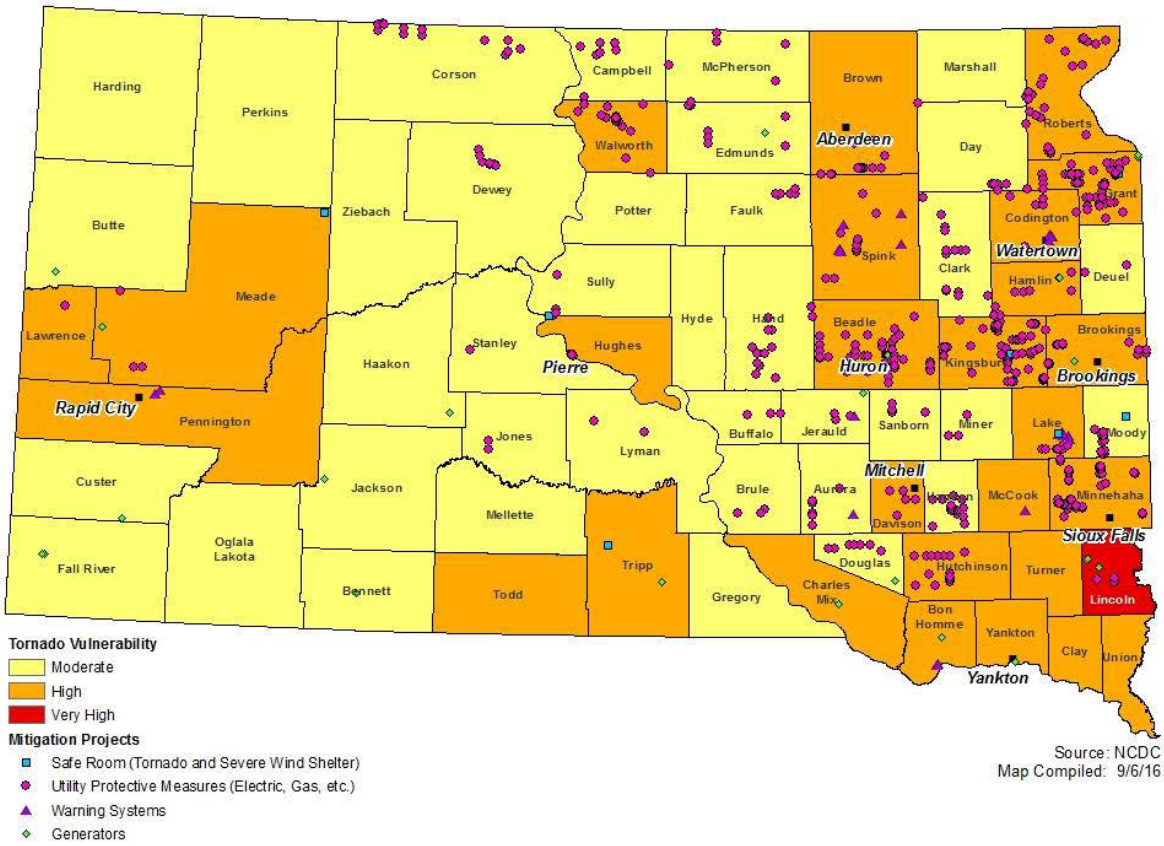


Table 3-60 Vulnerability of South Dakota Counties to Tornadoes

County	2016 Prior Event Rating	2016 Prior Event Rating ≥F1	Building Exposure Valuation Rating	Pop. Density Rating	Tornado Vulnerability	Tornado Vulnerability ≥F1
Lincoln	**6**	**8**	**9**	9	Very High	Very High
Brown	**10**	**10**	**8**	8	High	High
Minnehaha	**5**	**8**	**10**	10	High	Very High
Pennington	**5**	**7**	**10**	8	High	High
Union	**6**	**6**	**7**	8	High	High
Codington	**4**	**4**	**8**	8	High	High
Yankton	**4**	**6**	**8**	8	High	High
Davison	**3**	**5**	**7**	9	High	High
Turner	**5**	**8**	**6**	6	High	High
Brookings	**3**	**4**	**8**	8	High	High
Beadle	**4**	**6**	**7**	7	High	High
Lawrence	**2**	**4**	**8**	8	High	High
Clay	**4**	**5**	**6**	8	High	High
Meade	**5**	**8**	**7**	5	High	High

County	2016 Prior Event Rating	2016 Prior Event Rating ≥F1	Building Exposure Valuation Rating	Pop. Density Rating	Tornado Vulnerability	Tornado Vulnerability ≥F1
Hutchinson	**5**	**7**	**6**	5	High	High
Lake	**2**	**5**	**7**	7	High	High
Charles Mix	**5**	**9**	**6**	5	High	High
Roberts	**3**	**6**	**6**	6	High	High
Hughes	**1**	**3**	**7**	7	High	High
Bon Homme	**3**	**6**	**5**	6	High	High
Kingsbury	**5**	**6**	**5**	4	High	High
Hamlin	**2**	**3**	**5**	6	High	High
Grant	**2**	**3**	**5**	6	High	High
Spink	**5**	**5**	**5**	3	High	High
Todd	**4**	**4**	**4**	5	High	High
Walworth	**3**	**5**	**5**	5	High	High
Tripp	**4**	**6**	**5**	3	High	High
McCook	**5**	**8**	**3**	3	High	High
Moody	**1**	**3**	**5**	6	Moderate	High
Fall River	**4**	**6**	**5**	3	Moderate	High
Oglala Lakota	**2**	**4**	**5**	5	Moderate	High
Day	**3**	**3**	**5**	4	Moderate	Moderate
Deuel	**2**	**3**	**4**	5	Moderate	Moderate
Custer	**1**	**4**	**6**	4	Moderate	High
Butte	**2**	**4**	**5**	4	Moderate	High
Douglas	**3**	**4**	**3**	5	Moderate	Moderate
Marshall	**2**	**4**	**4**	5	Moderate	High
Brule	**3**	**5**	**4**	4	Moderate	High
Hand	**4**	**5**	**4**	2	Moderate	Moderate
Gregory	**3**	**4**	**4**	3	Moderate	Moderate
Hanson	**2**	**4**	**3**	5	Moderate	Moderate
Clark	**3**	**6**	**4**	3	Moderate	High
McPherson	**3**	**4**	**4**	3	Moderate	Moderate
Edmunds	**2**	**3**	**4**	3	Moderate	Moderate
Lyman	**4**	**6**	**3**	2	Moderate	Moderate
Sanborn	**3**	**4**	**3**	3	Moderate	Moderate
Perkins	**5**	**6**	**3**	1	Moderate	Moderate
Miner	**4**	**6**	**2**	3	Moderate	Moderate
Stanley	**3**	**4**	**3**	2	Moderate	Moderate
Aurora	**2**	**2**	**3**	3	Moderate	Moderate
Dewey	**3**	**3**	**3**	2	Moderate	Moderate
Bennett	**3**	**4**	**2**	3	Moderate	Moderate
Buffalo	**2**	**2**	**1**	3	Moderate	Moderate
Faulk	**2**	**3**	**3**	2	Moderate	Moderate
Haakon	**3**	**5**	**3**	1	Moderate	Moderate
Jerauld	**2**	**3**	**2**	3	Moderate	Moderate
Potter	**2**	**5**	**3**	2	Moderate	Moderate
Corson	**3**	**2**	**2**	1	Moderate	Moderate

County	2016 Prior Event Rating	2016 Prior Event Rating ≥F1	Building Exposure Valuation Rating	Pop. Density Rating	Tornado Vulnerability	Tornado Vulnerability ≥F1
Campbell	**2**	**3**	**2**	2	Moderate	Moderate
Sully	**2**	**3**	**2**	1	Moderate	Moderate
Jackson	**2**	**4**	**2**	1	Moderate	Moderate
Ziebach	**3**	**3**	**1**	1	Moderate	Moderate
Harding	**2**	**3**	**1**	1	Moderate	Moderate
Hyde	**1**	**2**	**2**	1	Moderate	Moderate
Jones	**1**	**2**	**1**	1	Moderate	Moderate
Mellette	**1**	**2**	**1**	1	Moderate	Moderate

Future vulnerability

Based on the map showing the location of mitigation projects associated with tornadoes (safe rooms, warning systems, utility line burials and generators) the future vulnerability of many of the high and very high ranked counties will be lessened to a degree by these projects. Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. These growth and development trends must be taken into consideration when reviewing the vulnerability results. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. However, future growth in any county may alter the increased future vulnerability to tornado events, as density increases (which increases the potential for catastrophic damages) or as more population becomes exposed. This should be carefully monitored in the southeast corner of the state.

Table 3-61 Tornado Consequence Table

Category	Narrative
Impact on the Public	Anyone without adequate shelter during an event at high risk of injury and death; impacts will be localized to the immediate area around the tornado path.
Impact on the Economic Condition of the State	Potential loss of facilities or infrastructure function or accessibility and uninsured damages; impact to transportation sector and movement of goods.
Impact on the Environment	Significant impact related to tree damage; possible cascading water quality issues from damaged water treatment facilities. Debris issues.
Impact on Property,	Buildings, vehicles, signage and/or any exposed or unsecured

Facilities, and Infrastructure	property may be affected during a tornado; property may be destroyed or have significant damage.
Impact on the Public Confidence in Government	Public holds high expectations of government capabilities for warning, public information, and response and recovery activities related to a tornado; high expectations for rapid restoration of critical facilities. Ability to respond and recover may be impaired if planning, response, and recovery not timely and effective.
Impact on Responders	Exposure exists to personnel performing routine duties when event occurs; storm-related duties are primarily post-event, however unsafe structural or environmental conditions may persist during the response period.
Impact on Continuity of Operations	Loss of facilities or infrastructure function or accessibility or ability to provide services; power interruption is likely if not adequately equipped with backup generation.
Cascading Hazards	

Windstorms

Methodology

To assess the vulnerability of each of South Dakota's counties to windstorm events, the state assigned ratings to three factors that were examined at the county level: prior events, building exposure, and population density. The state then summed the ratings to obtain overall vulnerability scores for each county so that they could be compared and greatest vulnerability determined. Ratings were applied to each factor and summed to obtain overall vulnerability scores for each county to allow comparison for greatest relative vulnerability. The methodology is further detailed in Appendix 3D South Dakota Vulnerability Methodology.

Total Windstorm Vulnerability and Estimate of Potential Loss

According to this methodology, every South Dakota county is vulnerable to windstorm but some counties have a higher risk than others. In addition, the vulnerability can vary slightly based on the severity of windstorm events. In both scenarios, Pennington, Minnehaha, Meade, and Brown had very high vulnerability. This is largely due to the counties' high ratings for building exposure and population density. When windstorm events of at least 70 knots or that caused damage, injuries, or fatalities are considered, Minnehaha, Pennington, Lincoln, Brookings, Yankton, and Meade have high vulnerability. Figure 3-70 illustrates the vulnerability of South Dakota counties to windstorm, and Table 3-62 shows all the South Dakota counties ranked by total windstorm vulnerability along with their three vulnerability

factor ratings. In general, the counties with the greatest vulnerability to windstorm events are those in the Black Hills region and those with major cities.

It is difficult to pick an area of higher vulnerability to windstorms in the state if all windstorm events are examined. Counties where at least 100 events have been recorded are fairly evenly distributed across the state. Counties with at least 150 reported events are centralized in the Black Hills region, and then include the counties of Hughes, Brown, Beadle, Davison and Minnehaha. When counties receiving a past events rating higher than 5 for events of at least 70 knots are plotted, they are distributed in the southeast corner of the state and in the Black Hills region.

Figure 3-70: Windstorm Vulnerability and State Facilities

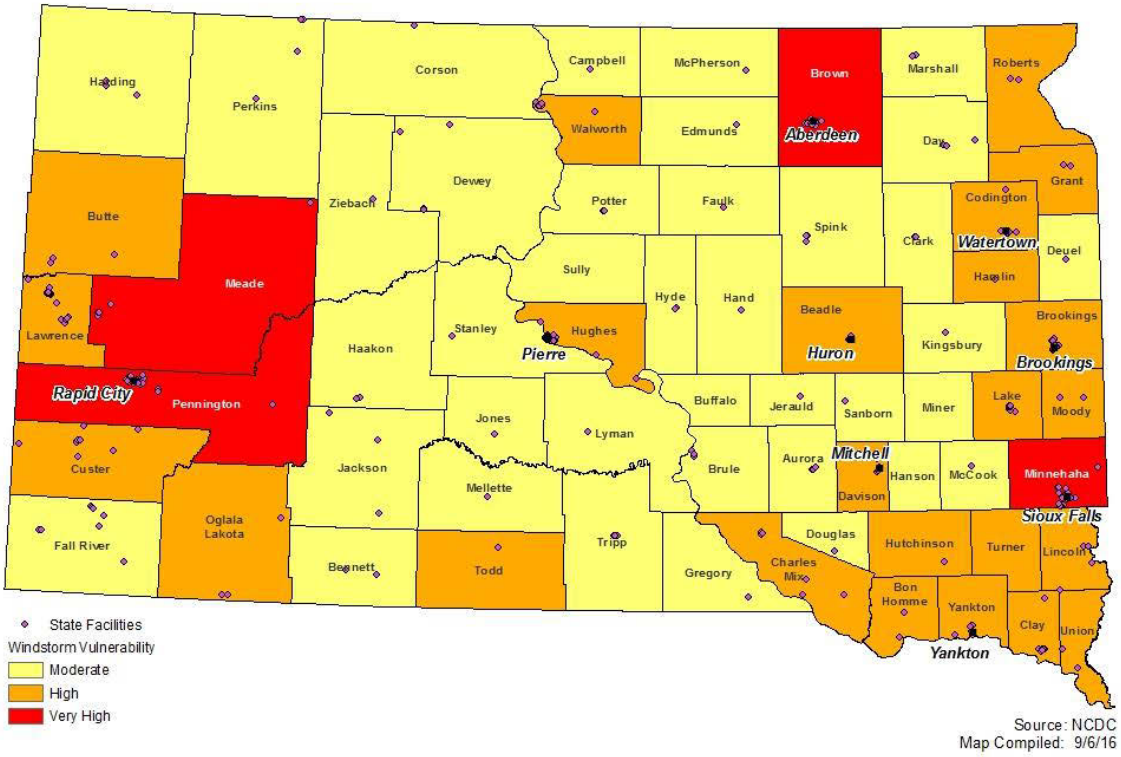


Figure 3-71: Windstorm Vulnerability and Mitigation Projects

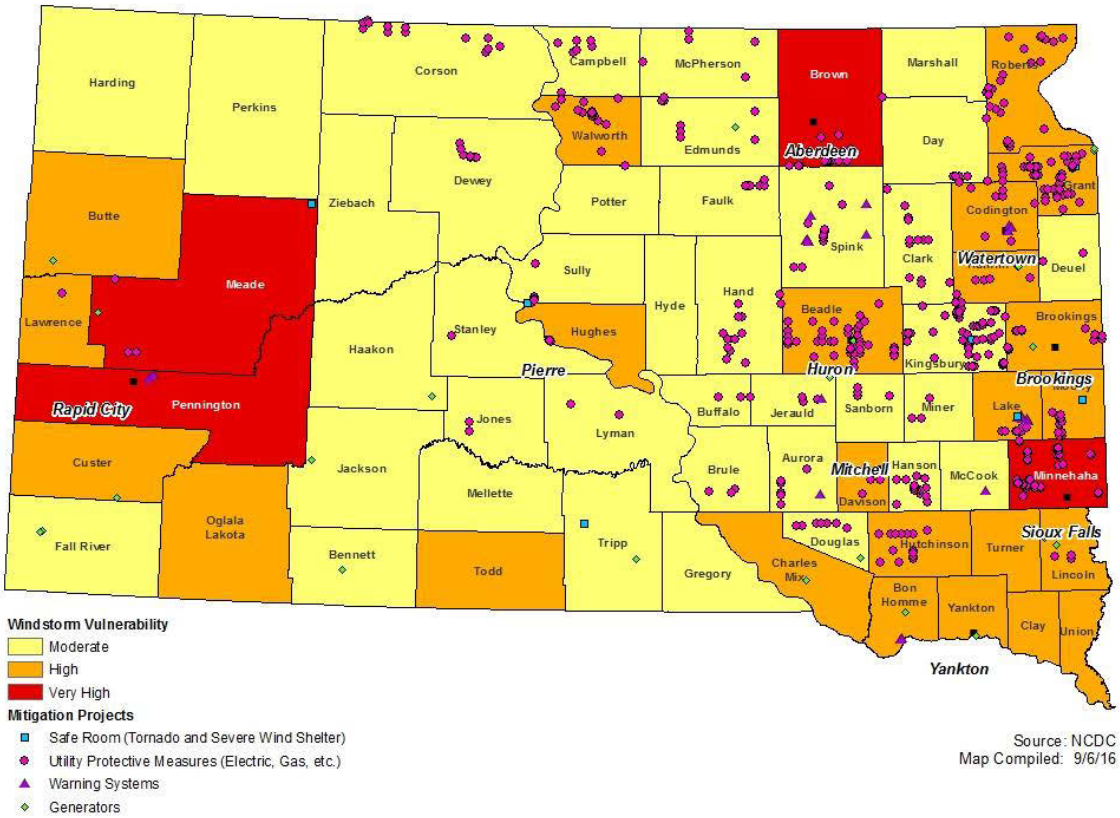


Table 3-62 Vulnerability of South Dakota Counties to Windstorm

County	Prior Event Rating	Building Exposure Valuation Rating	Pop. Density Rating	Windstorm Vulnerability
Brown	6	8	8	Very High
Meade	10	7	5	Very High
Minnehaha	6	10	10	Very High
Pennington	9	10	8	Very High
Beadle	5	7	7	High
Bon Homme	2	5	6	High
Brookings	3	8	8	High
Butte	5	5	4	High
Charles Mix	3	6	5	High
Clay	2	6	8	High
Codington	3	8	8	High
Custer	4	6	4	High
Davison	3	7	9	High
Grant	1	5	6	High
Hamlin	1	5	6	High
Hughes	4	7	7	High
Hutchinson	2	6	5	High
Lake	2	7	7	High

County	Prior Event Rating	Building Exposure Valuation Rating	Pop. Density Rating	Windstorm Vulnerability
Lawrence	1	8	8	High
Lincoln	3	9	9	High
Moody	1	5	6	High
Roberts	1	6	6	High
Oglala Lakota	3	5	5	High
Todd	3	4	5	High
Turner	2	6	6	High
Union	2	7	8	High
Walworth	3	5	5	High
Yankton	2	8	8	High
Aurora	1	3	3	Moderate
Bennett	2	2	3	Moderate
Brule	2	4	4	Moderate
Buffalo	1	1	3	Moderate
Campbell	2	2	2	Moderate
Clark	2	4	3	Moderate
Corson	4	2	1	Moderate
Day	2	5	4	Moderate
Deuel	1	4	5	Moderate
Dewey	2	3	2	Moderate
Douglas	1	3	5	Moderate
Edmunds	3	4	3	Moderate
Fall River	2	5	3	Moderate
Faulk	2	3	2	Moderate
Gregory	1	4	3	Moderate
Haakon	4	3	1	Moderate
Hand	2	4	2	Moderate
Hanson	1	3	5	Moderate
Harding	6	1	1	Moderate
Hyde	1	2	1	Moderate
Jackson	3	2	1	Moderate
Jerauld	1	2	3	Moderate
Jones	1	1	1	Moderate
Kingsbury	2	5	4	Moderate
Lyman	3	3	2	Moderate
Marshall	2	4	5	Moderate
McCook	2	3	3	Moderate
McPherson	1	4	3	Moderate
Mellette	1	1	1	Moderate
Miner	1	2	3	Moderate
Perkins	5	3	1	Moderate
Potter	2	3	2	Moderate
Sanborn	1	3	3	Moderate
Spink	3	5	3	Moderate
Stanley	3	3	2	Moderate
Sully	2	2	1	Moderate

County	Prior Event Rating	Building Exposure Valuation Rating	Pop. Density Rating	Windstorm Vulnerability
Tripp	3	5	3	Moderate
Ziebach	3	1	1	Moderate

To estimate potential losses to wind, historic loss data was analyzed. The National Climatic Data Center data did not lend itself to county by county loss summaries, only a statewide summary. Based on historic loss information presented in the wind hazard profile, South Dakota averages 123.3 windstorms, $2.605 million in wind losses, and roughly two injuries each year. The average cost of a windstorm in South Dakota is $21,137. The state has also experienced 1,841 events since 1955 with a wind speed of at least 70 knots, which accounted for three deaths and 67 injuries. This averages out to 27 particularly severe storms per year with an average yearly cost of $1.385 million. In addition, South Dakota has experienced three windstorms that resulted in a disaster declaration. Of these three events, the event on July 22, 2005 was credited entirely to wind, while the other two events also included damages from flooding and/or tornadoes. The total FEMA disaster relief costs for these three events are estimated at over $121.6 million in 2012 dollars, with an average cost of $40.5 million (also in 2012 dollars.) Based on past events, South Dakota can expect a disaster declaration-level windstorm event every 2,342 events or once approximately every 21 years.

Future vulnerability

Based on the map showing the location of mitigation projects associated with windstorms (safe rooms, warning systems, utility line burials and generators) the future vulnerability of many of the high and very high ranked counties will be lessened to a degree by these projects as there is a lot of corresponding overlap. Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. These growth and development trends must be taken into consideration when reviewing the vulnerability results. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. Population increases, and the associated growth of development, increases a county's risk to damages and losses from windstorms. In general, livestock are not severely impacted by windstorms although particularly severe events or events that cause a drastic change in the environment (such as wind chill) may incur disproportionate losses in livestock relative to the rest of the hazard events, therefore agricultural counties may also have periodic increases of vulnerability to events.

Table 3-63 Windstorm Consequence Table

Category	Narrative
Impact on the Public	Anyone without adequate shelter during an event at high risk of injury; impacts will be localized to the immediate area around the windstorm; air quality from blowing dust could have detrimental heath impacts.
Impact on the Economic Condition of the State	Potential damage to facilities or infrastructure; economic impacts from prolonged power outages.
Impact on the Environment	Significant impact related to tree damage. May contribute to soil erosion and dust storms.
Impact on Property, Facilities, and Infrastructure	Buildings, vehicles, signage and/or any exposed or unsecured property may be affected during a tornado; property may be destroyed or have significant damage. Older buildings more susceptible to damage.
Impact on the Public Confidence in Government	Ability to respond and recover may be impaired if planning, response, and recovery not timely and effective.
Impact on Responders	Unsafe structural or environmental conditions may persist during the response period.
Impact on Continuity of Operations	Loss of facilities or infrastructure function or accessibility or ability to provide services; power interruption is likely if not adequately equipped with backup generation.
Cascading Hazards	Exacerbates wildfire, drought and winter storm hazards.

Hazardous Materials

It is difficult to quantify trends in hazardous materials transportation incidents due to their somewhat random nature, but based on historic incidents more than half of the transportation incidents between 1971 and 2012 occurred in Minnehaha and Pennington counties, where the state's largest cities, Sioux Falls and Rapid City, are located. These counties are trailed by Brown, Codington, and Brookings in terms of numbers of incidents. Based on the information in the hazard profile section, South Dakota experienced 760 transportation incidents involving hazardous materials between 1971 and 2012, an increase of 51 events since the 2010 plan. The total cost of damage associated with these incidents was approximately $6,537,056. This suggests that South Dakota experiences 18 transportation incidents

involving hazardous materials and $159,440 in related damage each year. Among these incidents there were 3 deaths and 16 injuries. In total, 357 people were evacuated. 16 of the incidents were rail related, 28 were air, and the remaining 716 were highway. Other concerns noted in the planning process are the transport of nuclear materials, which often occurs without the knowledge of local governments or tribal organizations.

Vulnerability to pipeline incidents was determined solely on the total number of miles of gas or hazardous liquid transmission lines, as detailed in the hazard profile section. Based on this table the top ten counties with the most transmission lines are Lincoln, Minnehaha, Brown, Clark, Spink, Butte, Hutchinson, Union, Harding, and Kingsbury, most of which are located in southeastern/eastern South Dakota. According to the U.S. Department of Transportation's PHMSA, there were 42 pipeline incidents in South Dakota between 1983 and 2012 (29 years), totaling $12,245,360, which equates to $422,254 in average annual loss. Pennington and Minnehaha each had 8 incidents in this time period, Beadle had 3, and Brown, Clark, Codington, Custer, Decatur, Kingsbury, Lawrence, Lincoln, McCook, Sanborn, Union, Walworth, and Yankton each had 2 or fewer.

Future vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. These growth and development trends must be taken into consideration when assessing vulnerability of jurisdictions to hazardous materials incidents. Although a high vulnerability for Brookings County did not arise in this plan, they may become more vulnerable to hazardous materials as the population increases and the transportation systems expand throughout the county. Southeastern counties are more vulnerable to fixed facility incidents in general due to the number of facilities there. The counties with these facilities are listed in the hazard profile section. Available data does not support further refinement of vulnerability to fixed facility incidents based on historic losses.

Table 3-64 Hazardous Materials Consequence Table

Category	Narrative
Impact on the Public	Impact is dependent upon characteristics of the chemicals associated with the incident. Health impacts from contamination in water or air; anyone without adequate shelter or appropriate protection during an event at high risk of injury and death.
Impact on the Economic Condition of the State	Potential loss of facilities or infrastructure; potential impact to tourism depending on severity and location of the event.
Impact on the Environment	Significant impact related to water quality and air quality; significant impact to animal habitats depending on location and severity.
Impact on Property,	Vulnerabilities to critical infrastructure, facilities, properties,

Facilities, and Infrastructure	equipment, vehicles, and communications and utility infrastructure.
Impact on the Public Confidence in Government	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective
Impact on Responders	Exposure exists to response personnel performing routine duties when event occurs; appropriate protection required.
Impact on Continuity of Operations	Potential loss of facilities or infrastructure function or accessibility or ability to provide services.
Cascading Hazards	

Geologic Hazards

Information regarding previous landslides, mudflows, and subsidence throughout the State of South Dakota was too limited, at the time of this plan update, to assess the vulnerability and potential losses by jurisdiction. Limited areas throughout the state are vulnerable to landslides and mudflows as depicted in the hazard profile. Available data does not support further refinement of vulnerability to landslides and mudflows based on historic losses. South Dakota Geological Survey has been updating county studies on swelling soils. Completed studies should be referenced during the next plan update.

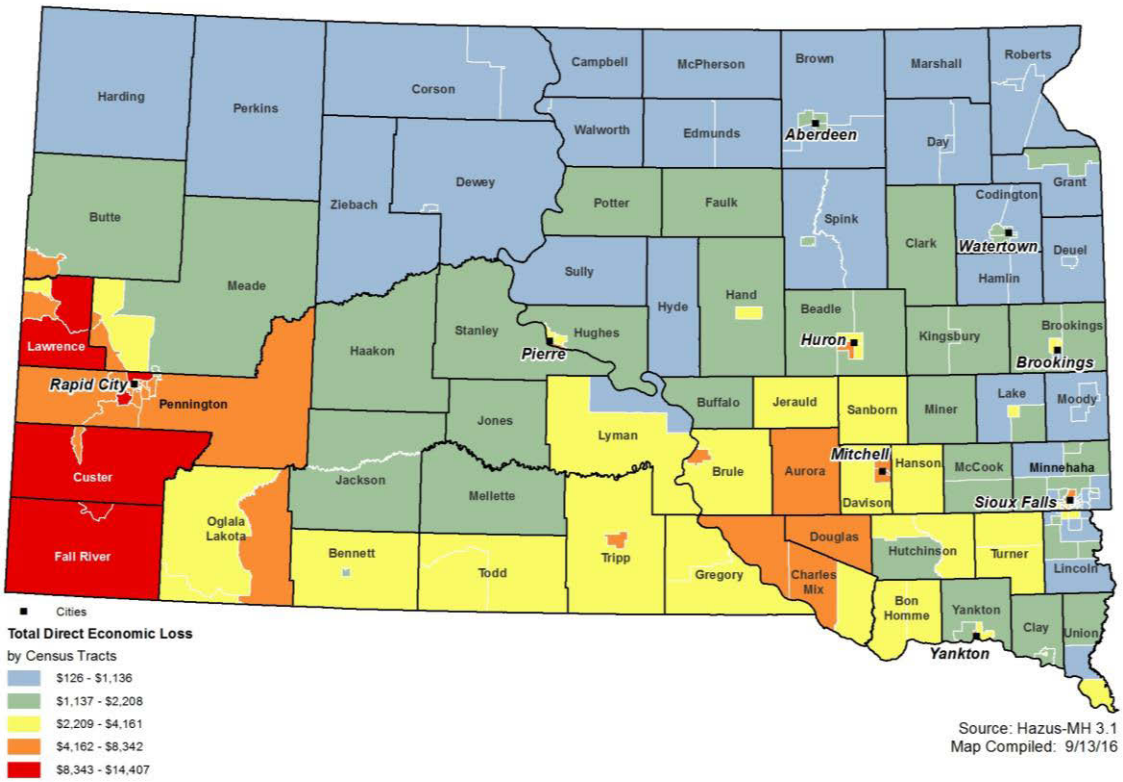
A HAZUS-MH annualized earthquake loss scenario was run for the entire state in the 2007 and again in 2016 to update this plan. This enabled a consistent comparison of earthquake risk across the state. Version 3.1 of HAZUS was used in 2016, which has inventory data based on 2010 Census data. The annualized expected loss (AEL) addresses key components of risk: the probability of hazard occurring in the study area, the consequences of the hazard (largely a function of building construction type and quality), and the intensity of the hazard event. By annualizing estimated losses, the AEL factors in historical patterns of frequent small events with infrequent larger events to provide a balanced presentation of the risk. In HAZUS-MH, losses are annualized over eight earthquake return periods (100, 200, 500, 750, 1,000, 1,500, 2,000, and 2,500 years).

The results of the annualized scenario indicate total economic loss estimated at $371.25 million. The building losses (includes building structure, content and income losses) totaled $0.6 million. 29% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 53% of the total loss.

A HAZUS-MH Probabilistic Scenario for a 2,500 year return period earthquake was run as well. This represents a worst case scenario. The results of this scenario indicate total economic loss estimated at $949.15 million. The building losses (includes building structure, content and income losses) totaled $578.51 million. 25% of the estimated losses were related to the business interruption of the region. The largest loss was sustained by the residential occupancies which made up over 55% of the total loss. 6,930 buildings would be at least moderately damaged with an estimated 62 buildings that will be damaged

beyond repair. The counties with the highest building losses are Pennington ($148,000), Minnehaha ($71,000), and Lawrence ($34,000), Davison ($20,000), Fall River($22,000), and Meade ($21,000) with the remaining counties having $20,000 or less in loss. Three casualties were generated by the scenario. The map below displays the probabilistic economic losses for a 2500 year earthquake in South Dakota.

Figure 3-72 HAZUS Probabilistic Earthquake: Direct Economic Losses For Buildings



Future vulnerability

Pennington and Codington counties identified population growth and construction of new homes in their local plans. Lincoln experienced the greatest population gain from 2000 – 2014 of all the counties in South Dakota. Campbell experienced the greatest population loss from 2000 – 2014. Minnehaha, Pennington, Union, Brookings, and Custer counties continue to increase their vulnerability as population and development increases by more than 15%. Areas with high development will continue to be the areas most vulnerable to structural damage from earthquakes. Site specific investigations and mitigation measures should help to limit future damages from expansive soils and landslides. SDDOT has plans to inventory the known active and/or previously addressed slide locations as part of the Department's overall asset management program. This initiative may not be completed for some time but should be revisited during the next plan update if the data is available.

Table 3-65 Landslides, Expansive Soils, Subsidence Consequence Table

Category	Narrative
Impact on the Public	Staff, recreationists, campers, property owners in remote areas may be at risk to injury or death from debris flows.
Impact on the Economic Condition of the State	Potential loss of facilities or infrastructure; potential impact to tourism and land development activities depending on severity; depending on nature of area where landslide occurs, many home based businesses will be impacted due to destruction of property.
Impact on the Environment	Impacts to water quality; erosion and sedimentation may affect critical infrastructure and natural waterways.
Impact on Property, Facilities, and Infrastructure	Vulnerabilities to critical infrastructure, facilities, properties, equipment, vehicles, and communications and utility infrastructure within landslide extent.
Impact on the Public Confidence in Government	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective
Impact on Responders	Exposure exists to response personnel performing routine duties when event occurs.
Impact on Continuity of Operations	Potential loss of facilities or infrastructure function or accessibility or ability to provide services. Power interruption is likely if near power lines.
Cascading Hazards	

Table 3-66 Earthquakes Consequence Table

Category	Narrative
Impact on the Public	Increase in sheltering and evacuation demands; vulnerable populations along fault lines will be severely impacted; while likelihood of a damaging event is rare there is potential for mass for injury or death from structural and non-structural building elements.
Impact on the Economic Condition of the State	Potential business impacts from facility damage, road closures and other transportation issues; potential loss of facilities or infrastructure function or accessibility and uninsured damages; debris management

	demands (costs/location).
Impact on the Environment	Environmental damage variable due to location and magnitude; possible cascading water quality issues from damaged water treatment facilities or impacts to ground and air quality from hazardous material leaks
Impact on Property, Facilities, and Infrastructure	Buildings, vehicles, signage, and/or any unsecured property may be damaged or destroyed during a significant event; Older and historic structures more vulnerable. Possible impacts to communications; expected damage to water treatment facilities, government buildings, public safety facilities, power generation and distribution, and healthcare facilities expected to be minor based on Hazus modeling. Potential for breaks and leaks in gas, water and waste water utility lines and associated disruption.
Impact on the Public Confidence in Government	Public holds high expectations of government capabilities for public information and response and recovery activities related to large scale disaster events such as earthquake; high expectations for rapid restoration of critical lifelines
Impact on Responders	Unsafe structural or environmental conditions may persist during the response period putting search and rescue personnel and other responders at risk; structural damage to hospitals, fire stations, police stations; scale of event will likely overwhelm local resources and require mutual aid assistance from outside the area of impact
Impact on Continuity of Operations	Loss of facilities or infrastructure function or accessibility or ability to provide services; power interruption is likely if not adequately equipped with backup generation; large scale of event will typically overwhelm emergency response and coordination services and may require mutual aid assistance from outside the impacted area
Cascading Hazards	Energy Disruption; Urban Fire; Dam/Levee Failure, Hazardous Materials

Rural Electric Cooperative Considerations

During the 2013-2014 update the Rural Electric Cooperatives (REC) were engaged as participants in the state planning effort. This discussion focuses on the potential hazard risks to REC's. During the 2013 update a REC data collection guide was developed to guide RECs on the information needed for refining

vulnerability and loss estimates in future updates. This includes a hazard identification and vulnerability assessment that can be used to help a REC identify its primary risks. The goal of this process is to produce information that may inform the State's hazard mitigation plan in future updates. This process may also help RECs identify possible projects that may be eligible for federal mitigation funding pre or post disaster. These guides were distributed to the RECs and should provide more data collection for integration and analysis in the HMP's next update cycle. In 2013 two of these were filled out by RECs and used to enhance the hazard profiles for winter storm, tornado, and wind, which are also the hazards noted as most significant from the RECs' perspective. Winter storms, wind and tornadoes pose the greatest risk to power lines and facilities operated by the REC's. These hazards can knock down power lines, which tend to be the most vulnerable elements of the electrical grid. To determine how this risk may vary across the various REC's an overlay analysis of REC was done to determine their intersection with and very high vulnerable counties for Winter Storms, Wind, and Tornadoes identified through the previous methods described. In 2016, the ranking scheme was changed from equal interval to natural breaks to refine the ranking system. This change allowed for the analysis to be done with all counties with "Very High" vulnerability to these hazards. The boundaries of the RECs are displayed in Figure 3-73. The results of the analysis are summarized in Table 3-67.

Figure 3-73 South Dakota Rural Electric Cooperative Boundaries

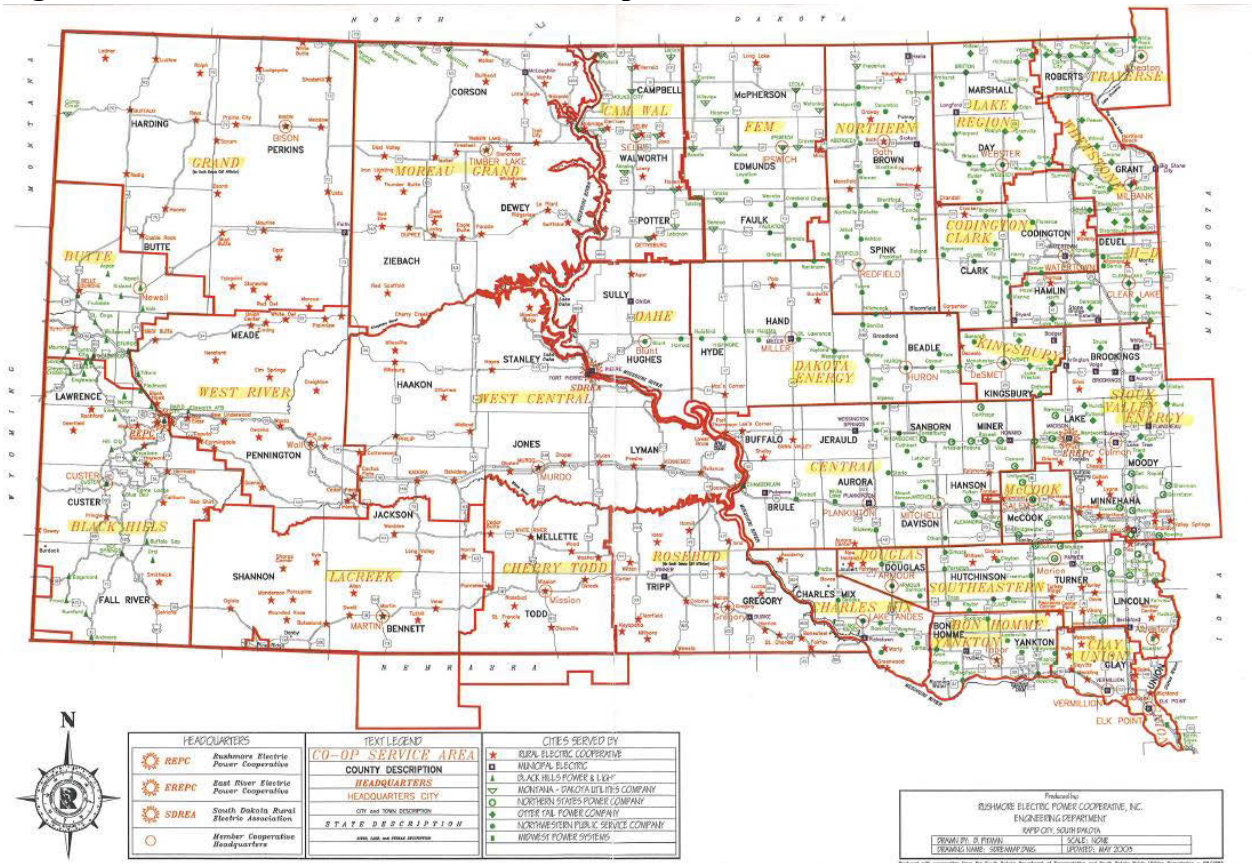


Table 3-67 Rural Electric Cooperative Hazard Vulnerabilities

Rural Electric Cooperative	County	Winter Storm Vulnerability	Wind Storm Vulnerability for events 70 kts or greater*	Tornado Vulnerability for events F1 or greater*
Black Hills Electric Cooperative, Inc.	Pennington	Very High	Very High	High
Black Hills Power & Light Co	Meade	Very High	Very High	High
Black Hills Power & Light Co	Pennington	Very High	Very High	High
Butte Electric Cooperative, Inc.	Meade	Very High	Very High	High
Central Electric Cooperative Inc.	Davison	Very High	High	High
Clay-Union Electric Corporation	Lincoln	Very High	Very High	Very High
Grand Electric Cooperative, Inc.	Meade	Very High	Very High	High
H-D Electric Cooperative, Inc.	Brookings	Very High	Very High	High
Kingsbury Electric Cooperative, Inc.	Brookings	Very High	Very High	High
Lake Region Electric Association, Inc.	Brown	Very High	High	High
MidAmerican Energy	Lincoln	Very High	High	Very High
Montana-Dakota Utilities Co	Brown	Very High	High	High
Northern Electric Cooperative Inc.	Brown	Very High	High	High
Northwestern Energy	Brown	Very High	High	High
Northwestern Energy	Davison	Very High	High	High
Otter Tail Power Co	Brookings	Very High	Very High	High
Sioux Falls Municipal Electric and Xcel Energy	Minnehaha	Very High	Very High	Very High
Sioux Valley Energy	Brookings	Very High	Very High	High
Sioux Valley Energy	Minnehaha	Very High	Very High	Very High
Southeastern Electric Cooperative, Inc.	Lincoln	Very High	High	Very High
Southeastern Electric Cooperative, Inc.	Minnehaha	Very High	Very High	Very High
Southeastern Electric Cooperative, Inc.	Turner	Moderate	High	High
West River Electric Association , Inc.	Meade	Very High	Very High	High
West River Electric Association , Inc.	Pennington	Very High	Very High	High
XCEL Energy	Lincoln	Very High	High	High
XCEL Energy	Minnehaha	Very High	Very High	Very High

*Also includes events that caused death or injury, or resulted in recorded financial damage

Based on this analysis notable REC's subject to risk from winter storm, wind, and tornadoes include:

- Black Hills Electric Coop
- Black Hills Power & Light Co.
- Clay-Union Electric Corporation
- MidAmerican Energy
- Sioux Falls Municipal Electric/Xcel Energy
- Sioux Valley Energy
- Southeastern Electric
- West River Electric

In addition wildfire can impact power lines in the Black Hills and parts of southeastern South Dakota (e.g. Lincoln County). The Black Hills, Butte, West River, and Southeastern REC's are more vulnerable to wildfires.

An overlay of power facilities on flood and wildfire hazard areas to identify specific facilities potentially at risk is discussed in the next section and captured in the tables in Appendix 3H.

South Dakota has funded several power line burial projects with HMGP funds in an effort to reduce future disaster losses. Data from disasters spanning (2005-2012) include 164 projects totaling $15.8M federal share. These projects are summarized in Table 3-68 . When comparing the data to Rural Electric Cooperative Hazard Vulnerabilities (Table 3-67), it does not appear that funding for REC mitigation projects is necessarily being spent in the areas with the highest vulnerability to windstorm, winter storm, or tornado. For example Minnehaha, McCook, and Pennington counties each ranked high or very high in vulnerability to at least one of the hazards, but the mitigation project data does not indicate investments in these counties. However, investments have been made in Lincoln, Brookings, Brown, and Davison counties which all had high or very high ranking in at least one of the three hazards. Additional data collection and analysis will be needed to estimate potential dollar losses to the REC's.

Table 3-68 REC Mitigation Funding and Miles of Line Buried by County: 2005-2012

Rural Electric Cooperative	County	Miles	Total Obligated
Central	Aurora	10.5	$452,376
Dakota Energy	Beadle	31.25	$721,257
Kingsbury	Brookings	0	N/A
Northern	Brown	16.25	$1,363,547
Central	Buffalo	3	$154,000
Cam-Wal	Campbell	19.9	$382,086
Codington-Clark	Clark	4	$244,398
Codington-Clark	Codington	3	$207,000
Moreau-Grand	Corson	30	N/A
Central	Davison	17.5	$466,143
Codington-Clark	Day	0	$162,546
H-D	Deuel	4	$132,908
Douglas	Douglas	1.5	$1,082,224
FEM	Edmunds	10	$145,283
FEM	Faulk	3	$216,204
Whetstone	Grant	29.5	$1,297,058
H-D	Hamlin	8	$326,809
Dakota Energy	Hand	19	$453,000

Rural Electric Cooperative	County	Miles	Total Obligated
Central	Hanson	19.75	$566,727
Southeastern	Hutchinson	22	$854,493
Kingsbury	Kingsbury	40	$935,538
Southeastern	Lincoln	0	$634,445
West Central	Lyman	0	$1,616,440
FEM	McPherson	4.5	$162,457
Central	Miner	9.5	$193,278
Traverse and Whetstone	Roberts	14	$916,386
Northern	Spink	18.5	$716,014
Oahe	Sully	1.2	$69,237
Cam-Wal	Walworth	8	$347,700
Moreau-Grand	Ziebach	0	$80,396

South Dakota has also used FEMA Public Assistance Section 406 mitigation to fund power line strengthening, burial, and retrofitting as part of project worksheets (PW) during post-disaster reconstruction. The table below summarizes the amount of projects and mitigation funding associated with Section 406 from disasters in 2008-2011 based on information provided by SDOEM. The damage category F mitigation dollars shown for DR1759 and DR1887 in the table below are primarily associated with power line burials or upgrades for REC's. DR1759 included funding for Grand Electric Coop and Butte Electric. DR 1887 included funding for Cam-Wal, Central, Dakota Energy, FEM, Grand, Moreau-Grand, and Whetstone Valley Electric cooperatives. Total mitigation funding from these two disasters is over $11M. Combined with the HMGP funding in the previous table the total includes over $26.8M in mitigation funds for the RECs since 2005.

Table 3-69 FEMA Public Assistance Section 406 Project and Mitigation Funding: 2008-2011

DR#	Type	Year	Damage Category	# of Applicants	# of PW's	Total
1984	Flood	2011	C	8	98	$745,578
1938	Flood	2010	C	12	14	$712,318
1947	Flood	2010	D+E	2	8	$86,870
1887	Winter Storm	2010	F	7	297	$9,596,751
1759	Winter Storm	2008	F	2	3	$1,458,213
						$12,599,729

3.4 Assessing Vulnerability and Estimating Potential Losses of State Facilities

44 CFR Part 201 Requirement:

[The State risk assessment shall include an overview and analysis of the State's vulnerability to the hazards described in paragraph (c) (2), based on estimates provided in] the State risk assessment. …State owned critical or operated facilities located in the identified hazard areas shall also be addressed….

The State shall update the overview and analysis of vulnerable State owned or operated buildings, critical facilities, and infrastructure, based on available data. The update should reflect acquisition or development of new properties and infrastructure.

44 CFR Part 201 Requirement:

[The State risk assessment shall include an overview and analysis of potential losses to identified vulnerable structures, based on estimates provided in] the State risk assessment. The State shall estimate the potential dollar losses to State-owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

South Dakota uses the following definitions from the National Infrastructure Protection Plan to define its infrastructure, critical infrastructure, and key resources:

Infrastructure: The framework of interdependent networks and systems comprising identifiable industries, institutions (including people and procedures), and distribution capabilities that provide a reliable flow of products and services essential to the defense and economic security of the United States, the smooth functioning of government at all levels, and society as a whole. Consistent with the definition in the Homeland Security Act, infrastructure includes physical, cyber, and/or human elements.

Critical Infrastructure: Assets, systems, and networks, whether physical or virtual, so vital to the United States that the incapacity or destruction of such assets, systems, or networks would have a debilitating impact on security, national economic security, public health or safety, or any combination.

Key Resources: As defined in the Homeland Security Act, key resources are publicly or privately controlled resources essential to the minimum operations of the economy and the government.

The State Office of Emergency Management has developed a database of Key Resources and Critical Infrastructure that combines state and local facility information. State owned or operated facilities are included in this database, based on input from state agencies. Using a geocoded database of government office buildings in the State from FEMA, OEM staff worked through a Technical Advisory Group (TAG), whose membership represents: Department of Tourism and State Development; Game, Fish and Parks; Bureau of Information and Telecommunication; Department of Public Safety; Department of Revenue and Regulation; Department of Environmental and National Resources; and Department of Transportation, to obtain available information regarding state owned or operated facilities.

Some local facilities are included in this database as well. The county emergency managers have contributed information on the facilities they feel align with the National Infrastructure Protection Plan

definitions. Some of this information is sensitive and has restricted public access. A non-restricted version of the GIS database was made available for analysis during this plan's update in 2007, 2010, 2013 and 2016. Improvements to the database could include the addition of a building valuation field and a standardized classification of facility type. These improvements are still recommended in 2016. The database included the following types of facilities:

- Educational/School
- Electric power
- Emergency services
- Energy
- Hydro Electric
- Hospitals
- Law Enforcement
- Natural Gas
- Communication
- Airports
- Water Facilities
- Waste Water Facilities
- Processing
- Storage stockpiles
- Local health department offices
- State penitentiary
- State office buildings\facilities

Five other GIS layers available from the South Dakota Department of Transportation contain additional information on utility-specific facilities, including:

- Water
- Communication
- Power
- Natural Gas
- Fuel

The State also provided a state buildings layer in GIS with state owned or leased facilities. The State did not have a complete utility/infrastructure layer, but several GIS layers were available from the South Dakota Department of Transportation. These layers included fuel, power, and natural gas utilities (point locations), and road and railroad networks. Utility networks included fiber optic, electric, natural gas, liquid petroleum, telecommunications, television and other networks. These layers were supplemented with national infrastructure data such as the National Inventory of Bridges and National Inventory of Dams and the Homeland Security Infrastructure Program (HSIP 2015) for the infrastructure vulnerability analysis.

Maps showing the general locations of the state buildings, critical facilities and utility infrastructure are included in Figure 3-75 and Figure 3-76. The scale of these maps is limited by the size constraints of this document. Images can be made available for large scale printing if desired or re-created from GIS.

Figure 3-74 South Dakota Total Building Exposure

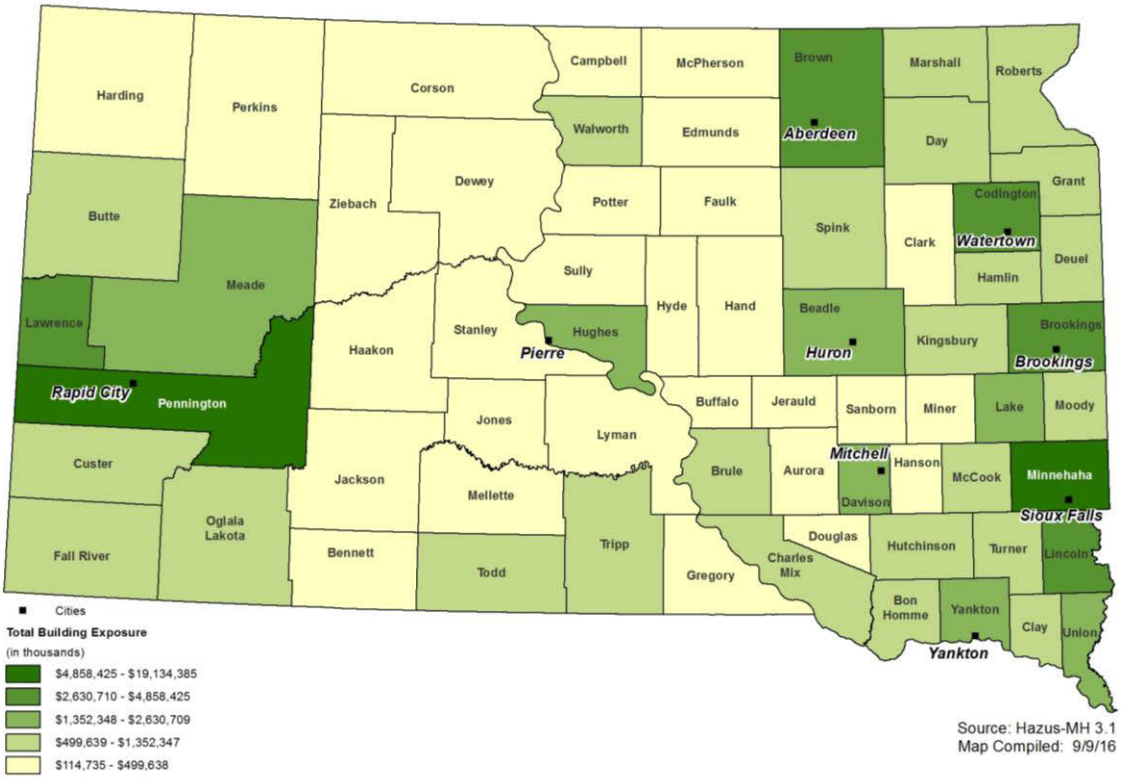


Figure 3-75 South Dakota State Facilities

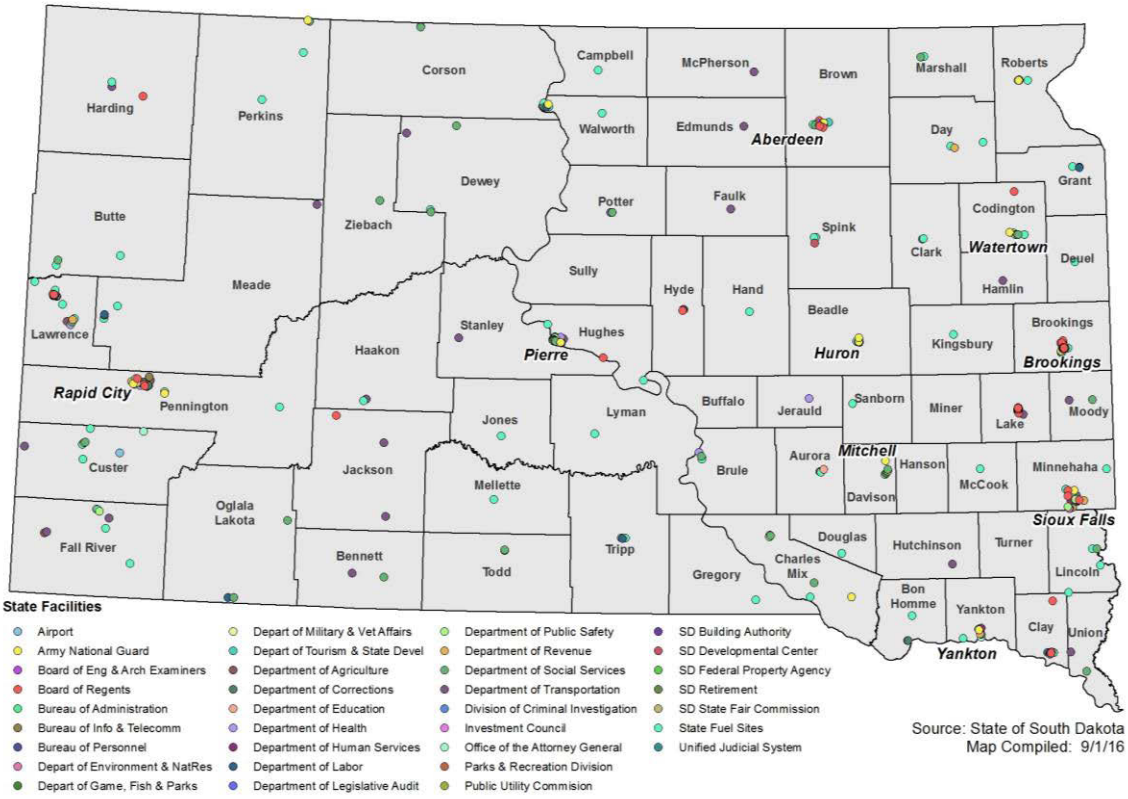


Figure 3-76 South Dakota Utilities

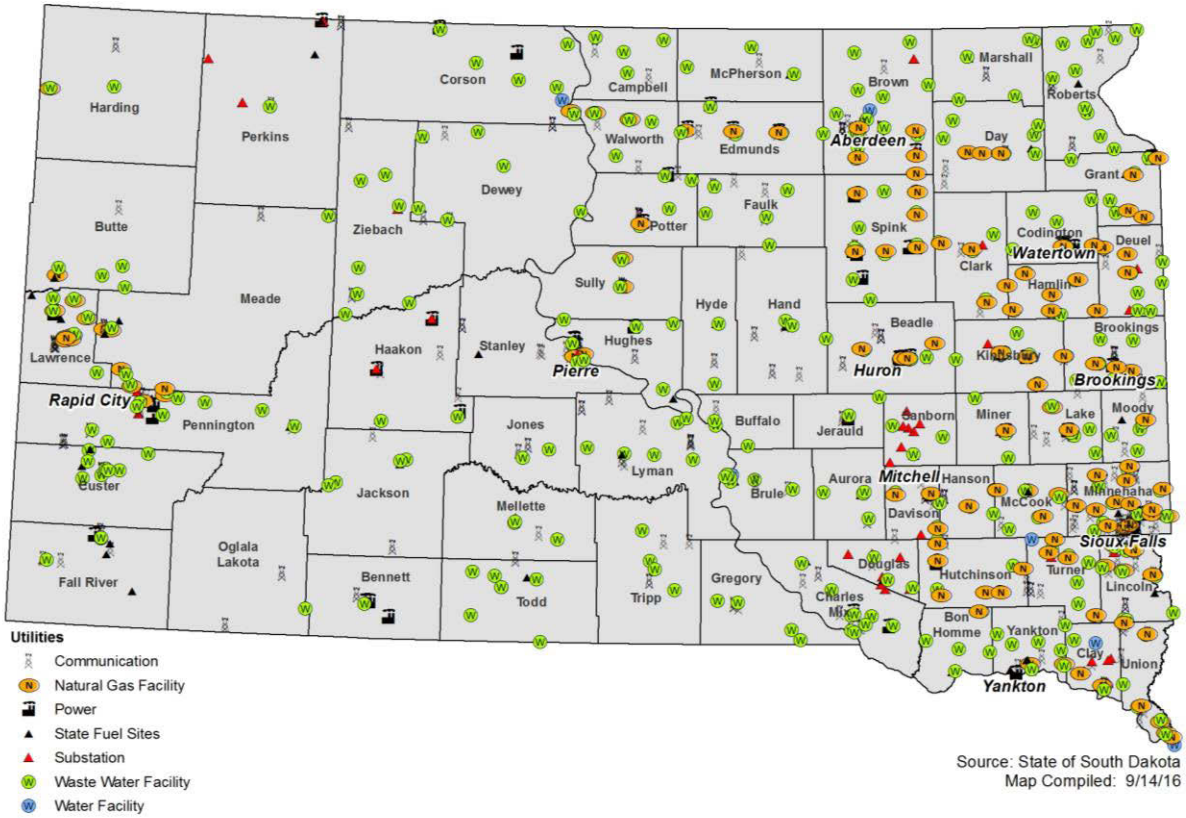


Figure 3-77 South Dakota Utility Infrastructure

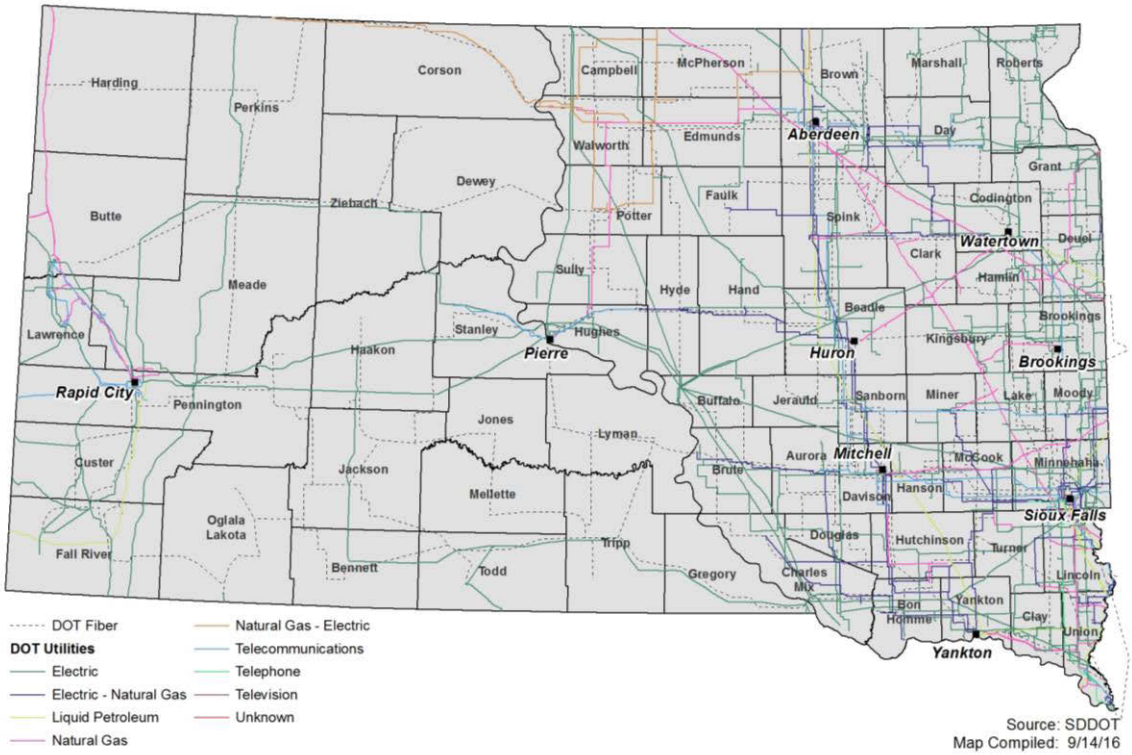
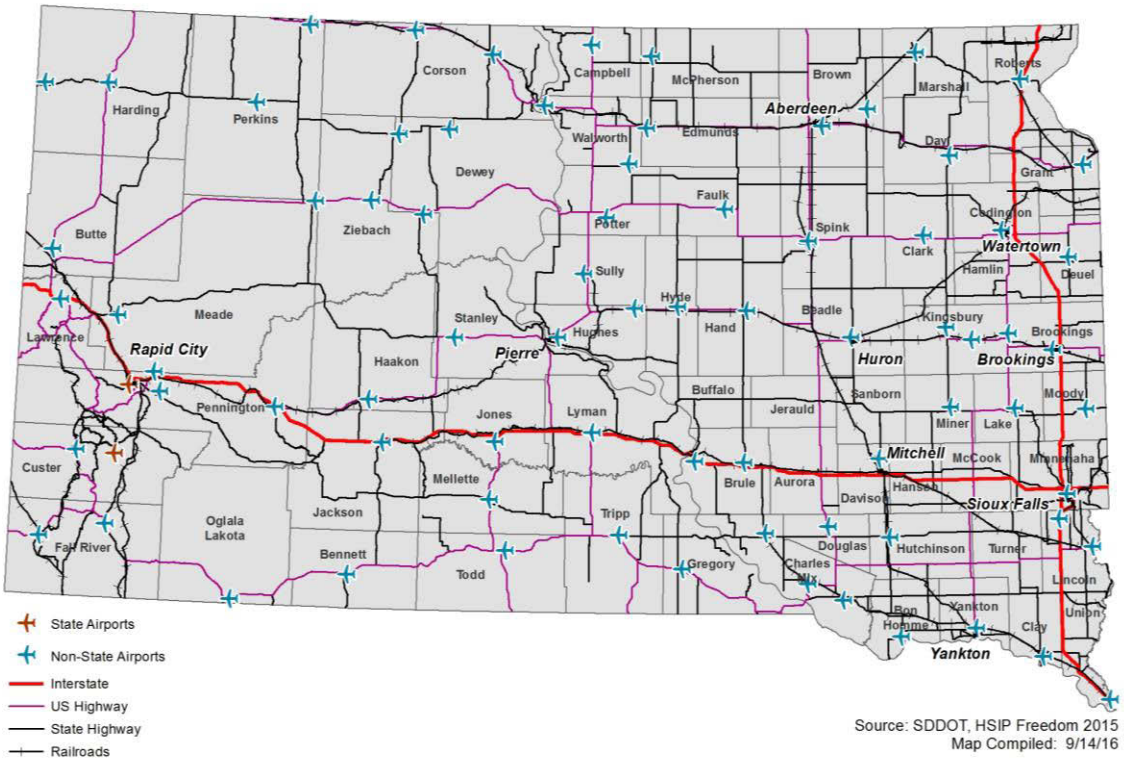


Figure 3-78 South Dakota Transportation Infrastructure



Methodology

The method used to determine vulnerability to state facilities was to overlay facilities data on digital hazard maps, where available, and identify those facilities potentially at risk. This method was used to determine vulnerability to floods and wildfire. For severe weather hazards including winter weather, tornadoes, wind, and drought it is generally accepted that these hazards could strike anywhere in the state at various levels of severity. An exposure analysis was used for these hazards. Exposure analyses are different from loss estimates in that they present facilities that may be exposed to these hazards, but do not attempt to estimate the amount of damages to be incurred during an event. Using the previous county by county risk assessments the state facilities have been shown on the summary vulnerability maps to show exposure in general terms. Available data does not support a detailed vulnerability and loss estimation for impacts on critical facilities from the following identified hazards: hazardous materials, landslides and mudflows, and earthquakes.

Building valuations are not included in the state's GIS-based facility data, thus an estimate of potential losses to state facilities is difficult to quantify. The state's facility data was used for location information to overlay the facilities with the hazard maps. During the 2013 update the following data on state buildings was provided as an estimate of the replacement values of facilities in the state. The state was in the process of updating replacement values of state facilities during the 2016 update and more current information was not available.

Table 3-70 State Owned Building Replacement Value Estimates: 2011-2012

Campus Name	Gross Sq. Ft.	Replacement Value		Average Cost per Sq. Ft.
		Low	High	
Capitol Complex, Pierre	585,818	$174,713,480	$277,461,225	$386
Other buildings, Pierre	369,741	$65,041,873	$90,336,174	$210
HSC, Yankton	377,048	$43,371,028	$60,237,540	$137
MDSP, Springfield	375,365	$42,561,669	$59,113,414	$135
State Training School, Plankinton	154,831	$24,399,209	$33,887,510	$188
SD Penitentiary, Sioux Falls	806,481	$154,706,515	$208,215,388	$225
SDSVI, Aberdeen	65,000	$8,512,593	$11,823,047	$156
SD Developmental Center, Redfield	530,683	$55,699,349	$75,565,475	$124
Star Academy, Custer	169,911	$23,300,353	$32,361,908	$164
SDSD, Sioux Falls	97,955	$11,647,572	$16,177,184	$142
Veteran's Home, Hot Springs	163,141	$18,432,548	$25,600,845	$135
State Fair, Huron	832,742	$27,334,020	$44,190,939	$43
Total	**4,528,716**	**$649,720,209**	**$934,970,649**	**$175**

Source: SHMT

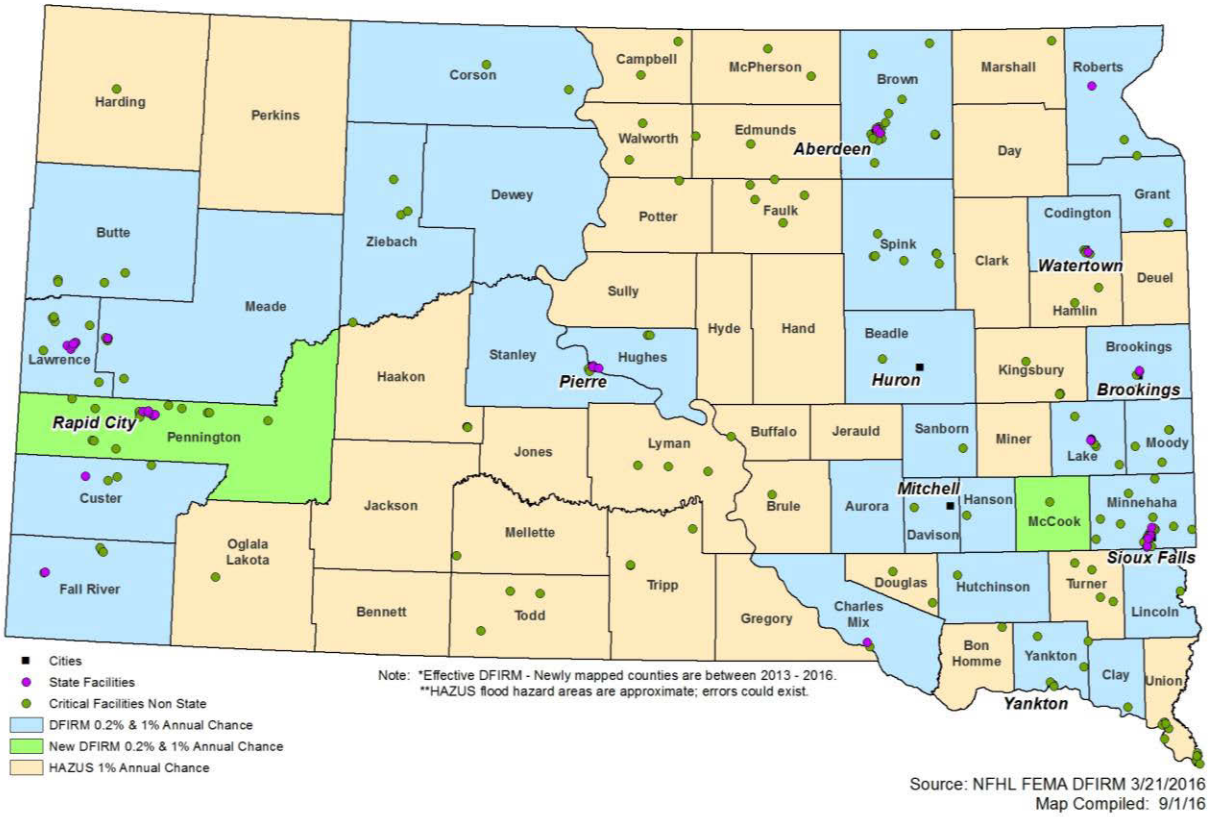
In order to further quantify the value of critical facilities and infrastructure in the state the best available data remains data extracted from HAZUS-MH data sets. HAZUS-MH breaks critical facilities into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

HAZUS-MH data includes all state owned and operated facilities as part of the total numbers of buildings, square feet, dollars and other pertinent information for each county. This data includes local and private assets such as electrical utility infrastructure maintained by the Rural Electric Cooperatives. The Government category in the building stock inventory includes all facilities owned and operated by the State of South Dakota as well as Schools, Police Departments, Fire Departments and Emergency Operations Centers. Using the exposure analysis approach, the total value of buildings included in these categories total approximately $837 million. Other essential facilities in HAZUS include 832 schools representing $374 million in potential losses, 54 hospitals with 4,538 beds representing $290 million in potential losses, 157 police stations, 278 fire stations and 24 emergency operations facilities representing $196 million, $65 million and $20 million in potential losses respectively. These numbers represent collectively state property at risk statewide from any disaster event. In HAZUS-MH there are utility and infrastructure data sets that are considered ‘lifeline’ inventory. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The total value of the lifeline inventory is over $80,019 (millions of dollars). This inventory includes over 11,937 kilometers of highways, 5,122 bridges, and 68,980 kilometers of pipes.

Floods

A GIS overlay analysis was performed to determine vulnerability of critical facilities to flooding. Both the latest available DFIRM (1% and 0.2% annual chance flood zones) and HAZUS-MH modeled base flood extents (in areas where DFIRM was not available) were used. Areas protected by levee were extracted from DFIRM data and also analyzed. Figure 3-79 illustrates critical facilities and their relationship to floodplains. Table 3H-D in Appendix 3H provides details on the numbers of facilities in the floodplain. The results of the analysis found 29 state facilities potentially at risk to flooding, based on both HAZUS and DFIRM mapping. Notable critical facilities and state assets at risk include 12 Board of Regents facilities and 3 Army National Guard. All state buildings are self-insured but do not carry flood insurance policies. There were 23 state facilities located within DFIRM 0.2% Annual Chance flood hazard zones, and four with areas protected by levees. Non-state critical facilities included 171 facilities, including 60 Tier II facilities. Limitations to this analysis include the number of counties with digital floodplains available, and the accuracy of the digital floodplains themselves, with the HAZUS-MH derived floodplains considered the less accurate of the two sources. This analysis does not consider if the building is elevated on fill or by other means, or flood proofed. .

Figure 3-79 South Dakota Critical Facilities and State Assets at Risk to Flooding



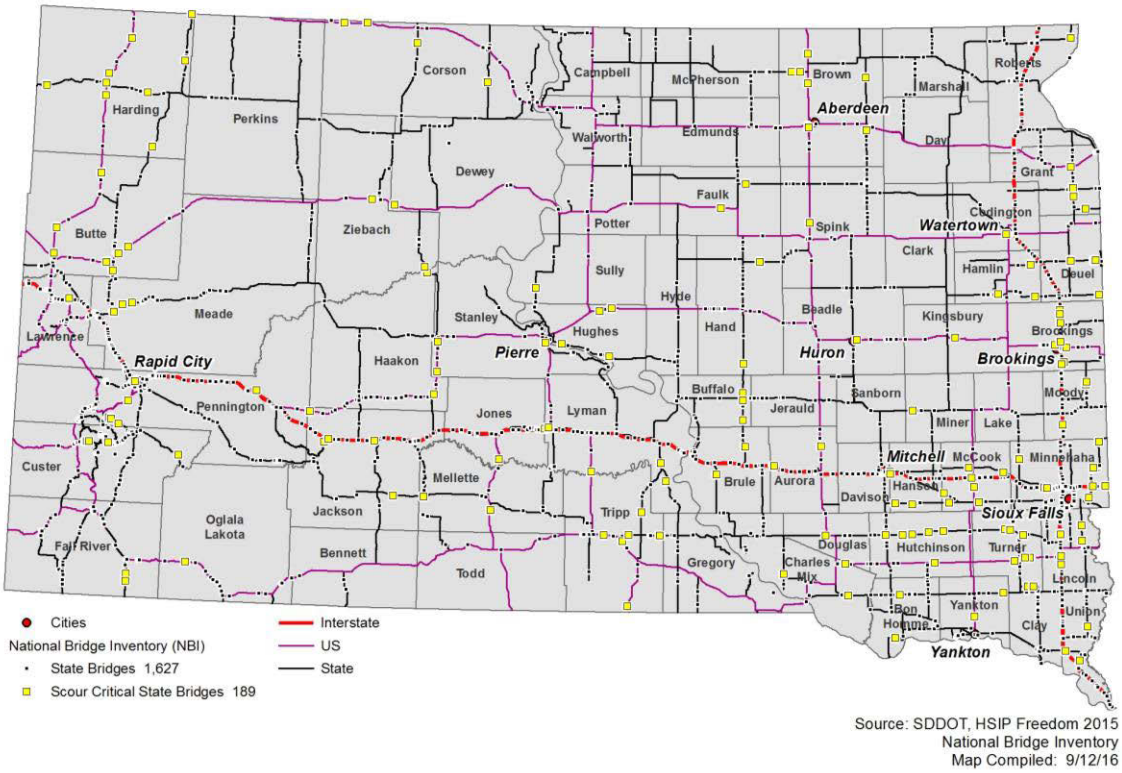
Analysis of Dams

According to information from the South Dakota Department of Natural Resources and the National Inventory of Dams, there are four high hazard dams in South Dakota that do not have emergency action plans, two of which are state regulated: Rank Dam in Buffalo County and Bruning No. 1 in Mellette County. Bruning No. 1 is the only state owned high hazard dam without an emergency action plan. The State DNR has made a concerted effort to improve the number of dams with emergency action plans. For example Kroetch dam in Haakon County is a state-owned dam that did not have an EAP in 2007 but now does. The other two high hazard dams that do not have plans are Major Lake Dam and Iron Creek Dam. The largest (based on normal storage volume) of the high hazard dams without emergency action plans is the privately owned Rank Dam in Buffalo County. Figure 3-7 illustrates the high and significant hazard dams in South Dakota. The State owns 180 of the 2,511 dams in the state. The majority of these dams are low hazard dams, 2,267.

Analysis of Scour Critical Bridges

Included with HAZUS-MH is a database of bridges called the National Bridge Inventory (NBI), which was developed by the Federal Highway Administration. One of the database items includes a "scour index" that is used to quantify the vulnerability of bridges to scour during a flood. Bridges with a scour index between 1 and 3 are considered "scour critical," or a bridge with a foundation element determined to be unstable for the observed or evaluated scour condition. Based on the NBI information submitted to the Federal Highway Administration in March 2016, there are 189 state-owned bridges identified as scour critical and 9 local government bridges. Additionally, there are 1,627 state owned bridges in the inventory with unknown foundations.

Figure 3-80 South Dakota State-Owned Bridges



During the 2007 update stakeholder meetings it was noted that railroads are vital to the rural farming economy in South Dakota, and that floods have impacted railroad bridges, delaying rail shipments of agricultural supplies for days or weeks. The NBI bridge database does not contain railroad bridges so further analysis of vulnerability could not be determined. Also noted during the planning process were the number of repeated culvert washouts and replacements on gravel roads from multiple flood disasters. Location and loss information from the FEMA Public Assistance program has been incorporated in updates to this HIRA.

According to the 2016 NBI report for South Dakota, the state has 1,193 structurally deficient bridges (85 are state-owned) and 217 functionally obsolete bridges (92 are state-owned).

Wildfire

Analysis of wildfire impacts to critical facilities was done using a wildfire risk layer from SILVIS. GIS was used to identify the critical facilities that lie within a high or moderate wildfire risk zone. A total of 481 facilities were identified statewide. Descriptions of the facilities potentially at risk are listed in Table 3H-E in Appendix 3H.

Tornadoes, Wind, and Winter Storms

An exposure analysis was used to identify the number of critical facilities in the counties most susceptible to tornadoes, wind, and winter storm hazards, based on the assessment of vulnerability by jurisdiction section. Fifteen counties were identified to have either 'very high' vulnerability to one or more of these hazards. The number of state facilities and other critical facility GIS layers (State Layer, Power, Natural Gas, and Fuel) was quantified in each of these counties. The results are displayed in Table 3-71. Due to the general nature of this exposure analysis individual facilities are not identified, but more detail can be reference in the state's GIS layers. The table also displays overlap in vulnerability to the three hazards, particularly in Brown, Meade, Lincoln, Minnehaha and Pennington counties. The mitigation strategies for these hazards often overlap as well, and this table indicates where multi-hazard critical facility protection opportunities may lie. See also the maps in section 3.3 that show the spatial distribution of the state facilities on the counties vulnerable to windstorms, winter storms and tornadoes.

Table 3-71 State Facilities in Counties Vulnerable to Winter Storm, Wind, and Tornado Hazards

County	Winter Storm Vulnerability	Wind Vulnerability for events 70 kts or greater*	Tornado Vulnerability for events F1 or greater*	State Layer Facility Count	Power Facility Count	Natural Gas Facility Count	Fuel Facility Count
Brookings	Very High	High	High	9	1	1	-
Brown	Very High	Very High	High	14	2	1	1
Davison	Very High	High	High	10	-	1	1
Lake	Very High	High	High	5	1	1	1
Lincoln	Very High	Very High	Very High	4	1	1	1
Meade	Very High	Very High	High	5	-	1	1
Minnehaha	Very High	Very High	Very High	24	2	1	1
Pennington	Very High	Very High	High	28	2	1	1
Yankton	Very High	Very High	High	7	1	1	1

*Also includes events that caused death or injury, or resulted in recorded financial damage

While these counties are considered more vulnerable, tornadoes, wind and winter storms can happen anywhere in the state with considerable impacts. It is noted that Hughes County includes Pierre, the state capital, and has the highest concentration of state owned buildings, facilities and employees. While rated 'moderate' in terms of vulnerability to the three hazards it does lie within Wind Zone III (200 mph design wind speed).

During the 2013 October blizzard, record amounts of snow developed on the SD Game Fish and Parks McNenny Fish Hatchery west of Spearfish. The excessive amounts caused the roof to fail and collapse in on itself. FEMA Public Assistance funding was used for the repairs.

Drought

In terms of state assets, state parks in South Dakota are likely to suffer the greatest impacts from drought, particularly those that provide water-based recreational activities. Direct losses to the state can include

lost revenue from park access fees. Other sources of state revenue that can be impacted by drought include hunting and fishing license sales. The SD Game Fish and Parks annual budget is reduced due to a decrease in hunting, fishing, and boating license sales. This is discussed further in the South Dakota Drought Mitigation Plan, though currently the GFP does not track license sales in a way that makes the sales data easy to access or analyze patterns in drought years vs non-drought years. Tracking these data would allow for an economic analysis of drought impacts to the GFP. Based on an account in the Drought Impact Reporter the South Dakota Game, Fish, and Parks Department noted that the state lost approximately $1 million in pheasant hunter license fees during the 2005 drought. The drought conditions reduced pheasant populations and, corresponding, pheasant hunter numbers across the state Available data does not support a more detailed vulnerability and loss estimation for drought impacts on non-state critical facilities. One example is power plants that generate hydroelectric power from dams on the Missouri River could be vulnerable to drought-reduced reservoir levels.

Hazardous Materials

Data available in 2016 allowed for a refined loss analysis of state facilities to both transportation and fixed facility incidents. To assess the vulnerability of state facilities to hazardous materials incidents, a GIS analysis was performed to detect state facilities within a 0.5 mile buffer of Tier II Facilities. The table below displays state facilities within this buffer. Based on this analysis Hughes (67 state facilities), Pennington (55), Brookings (37) and Brown (34) counties have the higher potential for hazardous materials incidents. More details can be found in Appendix 3H.

Table 3-72 displays state facility counts within the 0.5 mile buffer of a tier II facility. Based on this analysis the Board of Regents, State Fuel Sites, Department of Transportation and the Department of Social Services have the greatest exposure to a fixed facility hazardous materials incident.

Table 3-72 State Facilities within a 0.5 mile buffer of Tier II Facilities

State Facilities	Count
Airport	1
Army National Guard	21
Board of Eng & Arch Examiners	1
Board of Regents	137
Bureau of Administration	9
Bureau of Info & Telecomm	7
Bureau of Personnel	1
Depart of Environment & NatRes	4
Depart of Game, Fish & Parks	6
Depart of Military & Vet Affairs	2
Depart of Tourism & State Devel.	5
Department of Agriculture	7
Department of Corrections	17
Department of Education	3
Department of Health	13

State Facilities	Count
Department of Human Services	7
Department of Labor	24
Department of Legislative Audit	2
Department of Public Safety	14
Department of Revenue	13
Department of Social Services	30
Department of Transportation	49
Division of Criminal Investigation	1
Investment Council	1
Office of the Attorney General	5
Parks & Recreation Division	1
Public Utility Commission	1
SD Building Authority	1
SD Federal Property Agency	1
SD Retirement	1
SD State Fair Commission	1
State Fuel Sites	53
Unified Judicial System	1
Total	440

Table 3-73 displays state facility counts within the 0.5 mile buffer of railroad corridors within South Dakota. Based on this analysis the Board of Regents, Department of Transportation, State Fuel Sites, and the Department of Labor have the most risk for hazardous materials incidents.

Table 3-73 State Facilities within a 0.5 mile buffer of Railroad Corridors

State Facilities	Count
Army National Guard	12
Board of Eng. & Arch Examiners	1
Board of Regents	51
Bureau of Administration	8
Bureau of Info & Telecomm	4
Bureau of Personnel	1
Depart of Environment & NatRes	3
Depart of Game, Fish & Parks	5
Depart of Military & Vet Affairs	2
Depart of Tourism & State Devel.	4
Department of Agriculture	4
Department of Corrections	11
Department of Education	2
Department of Health	6

State Facilities	Count
Department of Human Services	6
Department of Labor	19
Department of Legislative Audit	2
Department of Public Safety	7
Department of Revenue	9
Department of Social Services	14
Department of Transportation	22
Office of the Attorney General	3
Parks & Recreation Division	1
Public Utility Commission	1
SD Building Authority	1
SD Federal Property Agency	1
SD Retirement	1
SD State Fair Commission	1
State Fuel Sites	21
Unified Judicial System	1
Total	**224**

Table 3-74 displays state facility counts within the 0.5 mile buffer of highways corridors within South Dakota. Based on this analysis the Board of Regents has the most at risk with 308 facilities. Other facilities at risk for hazardous materials incidents are State Fuel Sites, Department of Transportation, and the Department of Social Services.

Table 3-74 State Facilities within a 0.5 mile buffer of Highway Corridors

State Facilities	Count
Airport	1
Army National Guard	14
Board of Eng. & Arch Examiners	1
Board of Regents	308
Bureau of Administration	9
Bureau of Info & Telecomm	6
Bureau of Personnel	1
Depart of Environment & NatRes	3
Depart of Game, Fish & Parks	6
Depart of Military & Vet Affairs	3
Depart of Tourism & State Devel.	4
Department of Agriculture	7
Department of Corrections	13
Department of Education	4
Department of Health	13
Department of Human Services	6

State Facilities	Count
Department of Labor	22
Department of Legislative Audit	2
Department of Public Safety	13
Department of Revenue	9
Department of Social Services	29
Department of Transportation	74
Division of Criminal Investigation	1
Investment Council	1
Office of the Attorney General	5
Parks & Recreation Division	1
Public Utility Commission	1
SD Building Authority	1
SD Developmental Center	1
SD Federal Property Agency	1
SD Retirement	1
SD State Fair Commission	1
State Fuel Sites	82
Unified Judicial System	1
Total	**645**

Geologic Hazards

Resources and data did not support a detailed vulnerability and loss estimation for landslides, mudflow, expansive soil, and subsidence impacts on state facilities during the 2007, 2010, 2013, and 2016 updates to this plan. History has proven that earthquakes have not caused significant damage in the State of South Dakota. A 2,500 year probabilistic earthquake scenario was run in HAZUS-MH. The results showed no damage to critical facilities. While not specified in HAZUS, it is assumed that state facilities would have light to minimal impacts from earthquakes. The detailed results of this scenario are included as Appendix 3G.

Future Vulnerability of State Facilities

At the time this plan was prepared limited information regarding development of new state facilities was available. Significant population increases and decreases are outlined per county in Section 3.3.1 Growth and Development. These trends should be considered as existing facilities are maintained, improved, and or enhanced. The hazard areas identified in this plan are being considered when new state facilities are constructed. For example, a new prison in Rapid City was originally planned to be built within a floodplain. SDOEM has coordinated a new site for the prison outside of the floodplain.

An oil refinery is planned for development in Union County between state highways 48 and 50. This refinery may increase economic development in the county leading to an increase in population and

therefore an overall increase in vulnerability to natural hazards. The oil refinery may also cause vulnerability to man-made hazards generated by mishaps at the refinery. Operation of this facility began in 2014.

The former Home stake gold mine in Lead has been chosen by the National Science Foundation as a site for a multipurpose deep underground science and engineering laboratory. The underground laboratory and proposed Sanford Science Education Center will provide education and outreach opportunities.

3.5 Risk Assessment Summary and Conclusions

Although the majority of the state is vulnerable to all the hazards identified and discussed previously, impacts may vary widely in different areas of the state and at different times of year. The hazards as identified in Table 3-1 have impacted or have the potential to impact the citizens and governments of the state to one degree or another at any given time. However, based upon the research and analyses conducted for the HIRA over the years, it is evident that drought, floods, winter storms, wildfires, and tornadoes continue to require the most effort and expense in terms of response and recovery activities and their associated costs.

The following is a summary of the key vulnerabilities, losses and consequences associated with each hazard, based on the HIRA. This summary was added to the HIRA in 2016 to provide a quick reference for planners in the development of mitigation strategies.

Table 3-75 Hazard Risk Summary Table

Hazard	Vulnerability Summary/Problem Statements
Agricultural Pests and Diseases	• Significant pests and diseases include Foot and Mouth Disease, Trichomoniasis, Avian Influenza, West Nile Virus, Rabies, Asian Soybean Rust, Blight, Soybean Cyst Nematode • Diseases tracked for plants include sunflowers, canola, safflower, field pea, chickpea, lentil, dry bean, soybeans, corn, alfalfa, flax, winter wheat, spring wheat, barley, oats, rye • Track diseases for animals – cattle, swine, poultry, wildlife • Cattle losses $52 M in 2010 due to respiratory, digestive and other diseases • $9,626,082 in total indemnity payments between 2003 and 2015 in insect infestation; annual loss $740,468, according to USDA RMA • $6,713,015 in total indemnity payments between 2003 and 2015 in plan disease; annual loss $516,386, according to USDA RMA • $1,256,854 average annual losses statewide between 2003 and 2015 • Can have devastating impacts on agricultural economy statewide and beyond. • Ag sector impacts can be both direct (impacts to crops in the state) and indirect (impacts to the market from infestations elsewhere) • Livestock exposure greatest west of the Missouri River • Crop exposure greatest east of the Missouri River <u>State Facility and Critical infrastructure Impacts</u>

	• Risk to state owned/leased buildings and infrastructure is expected to be minimal • Other critical infrastructure impacts minimal • Climate change can alter and increase the range of many invasive weed species; increasingly powerful storms can exacerbate the spread of diseases; warmer temperatures can aid the spread of warm-weather pests into traditionally colder climates • Some outbreaks associated with drought or warmer than typical winters (grasshoppers, anthrax) • Overall Planning Significance: Moderate Significance
Summer Storms (Hail and Lighting)	• Added as new hazard profile in 2016 to align State HIRA with hazards identified in local Hazard Mitigation Plans <u>Hail</u> • Hail impacts vary based on hail diameter, duration, location and exposure • Over 10,200 separate records of hail incidents between 1996 and 2016 • $8,031,888 average annual property damage statewide between January 1, 1996 and May 30, 2016 for hail; total property damage $160,637,750 • $2,138,750 average annual crop damage statewide between January 1, 1996 and May 30, 2016 for Hail; total crop damage $42,775,000 • Average hailstone size in the state is 1.15"; largest recorded is 8" (Vivian, Lyman County, 7/23/2010) • NCDC records 38 hail-related injuries; no hail related deaths between 1996 and 2016 • 95% of recorded incidents did not cause property damage, crop damage, injuries or fatalities <u>Lightning</u> • Over 100 separate records of lightning incidents recorded between 1996 and 2016 • $108,560 average annual property damage statewide between January 1, 1996 and May 30, 2016 for Lightning; total property damage $2,171,200; no recorded crop damage during this timeframe • NCDC records 17 lightning-related injuries; five lightning-related deaths between 1996 and 2016 <u>State Facility and Critical infrastructure Impacts</u> • Risk to state owned/leased buildings and infrastructure is expected to be minimal; potential for hail damage to state-owned vehicles and roofs/windows of state facilities. • Other critical infrastructure impacts minimal; potential for limited energy disruption caused by lightning; critical points should be protected from exposure to hail and lightning • As climate change warms the earth and affects weather patterns, science shows that storms have generally become more intense, however research specific to hail and lighting is sparse. • Overall Planning Significance: Moderate Significance
Flood	• The greatest impacts have been to the eastern half of the state, principally, the

(Including Dam and Levee Failure)	Big Sioux, Vermillion, and James River basins, which have recurring problems.
	• Flood Insurance policy analysis in 2016 yielded:
	  o The number of policies statewide has fluctuated from 5,406 in 2010, 6,914 in 2012, to 4,684 in 2016. The higher policy count in 2012 is likely a carryover from flooding on the Missouri River in 2011 that generated a lot of interest in flood insurance.
	  o Statewide there has been $40,055,373 in flood loss claims since 1978, an increase of $3,037,150 from the $37,018,223 sum noted previously in the HIRA from November 2012.
	  o Flood loss claims increased from 3,316 in 2010 to 3,344 as of mid-2016.
	  o Flood loss claims result in an average annual loss of $1,054,088
	• Repetitive loss properties (2 or more claims in a ten year period) continue to be an issue. The 2016 repetitive loss statistics indicate:
	  o In 2012, the total amount in repetitive loss claims was $6,700,481. As of mid-2016, the total has increased to $9,581,367.
	  o The number of repetitive loss properties has increased by 10 since 2012; 28 counties now have repetitive loss properties, an increase of 2 since 2012 (Lincoln and Union added to list)
	  o The counties of Codington, Hamlin, Day, Minnehaha and Brown have the most repetitive loss properties.
	• Based on numbers of people and property at risk, i.e., the vulnerability of people and property at risk, the cities of Aberdeen, Pierre, Rapid City, Sioux Falls, and Watertown are at the greatest risk from flood events.
	• Dam failure flooding is included in the flood hazard profile. Of the roughly 2,500 dams, 155 are significant hazard and 89 are high hazard. The Majority of these dams are west of the Missouri River including concentrations in the Black Hills and along the Missouri River corridor.
	<u>State Facility and Critical infrastructure Impacts</u>
	• Risk to state owned/leased buildings and infrastructure includes the following based on GIS analysis:
	  o There are State facilities potentially at risk to flooding in the following counties: Lawrence, Meade, Pennington, Custer, Fall River, Hughes, Brown, Codington, Roberts, Brookings, Lake, Minnehaha, and Charles Mix.
	  o Of the critical facilities at risk, 392 are non-state critical facilities and 56 are state
	  o Within the DFIRM 1% Annual Chance category, 29 State Facilities and 171 Non State Facilities are at risk.
	  o Within the DFIRM 0.2% Annual Chance category, 23 State facilities and 81 Non State Facilities are at risk.
	  o Within the category "Area Protected by Levee," 4 State Facilities are at risk and 65 Non State Facilities are at risk.
	  o Facility valuation data was not available but could be used to refine exposure and loss estimates.
	• Roads and bridges impacts have resulted in numerous and costly disaster

	assistance claims. Analysis of FEMA PA funding from disasters between 1993 and 2014 indicates $203,909,385 have been spent on Category C (Roads and Bridges) and is assumed to represent flood-related public infrastructure damage. The majority of these claims are in the northeast corner of the state. • Climate change science indicates potential for increased potential for extreme rainfall events which could indicated increasing flood losses • Overall Planning Significance: High Significance
Winter Storm	• According to the National Climatic Data Center Storm Events database, there were 1,971 winter storms (snow and ice events) in South Dakota between January 1993 and March 2016, and 477 extreme cold events from January 1994 to March 2016. • Total property damage for these events is estimated at $91 million dollars. • South Dakota experiences 85 winter storms and $4 million in winter storm losses annually, as well as 20 extreme cold events each year. 12 deaths and 127 injuries were attributed to these events. • Approximately 1 death every other year and 6 injuries each year. • $3.3 million in winter-related crop loss indemnities each year based on RMA data • Cattle impacts have been significant • An updated statistical analysis resulted in 27 of the 66 counties with a moderate vulnerability ranking, 29 with a high ranking, and 8 with a very high ranking. Pennington and Minnehaha have the greatest amount of critical facilities at risk and very high vulnerability rankings. <u>State Facility and Critical infrastructure Impacts</u> • Winter storms have been particularly damaging to electric utilities. Analysis of FEMA PA funding from disasters between 1993 and 2014 indicates $466,422,028 spent on Category F-Utilities, which is assumed to largely represent winter storm losses. This equates to an average annual loss of $21,201,001. • Direct impacts to state owned facilities are not likely to result in losses, but winter storms can temporarily disrupt travel on local, state and federal highways and result in significant expenses associated with snow removal and first responders assisting stranded travelers. • Climate change EPA research indicates that the amount of winter precipitation and the number of days with heavy snowfall are projected to increase in northern states. A warming climate may also result in warmer winters. • Overall Planning Significance: High Significance
Wildfire	• Forests in the Black Hills of western South Dakota have many more trees per acre and much more undergrowth, needle litter and deadwood than it did historically. • Mountain pine beetle attacks in Ponderosa Pine often coincide with abundant weak trees resulting from drought and overgrown conditions, resulting in higher fuel loads. • The greatest concentration of Wildland Urban Interface (WUI) structures is located in and around the communities in the Black Hills. Rapid City and bedroom communities within a five-mile radius of the city represent the greatest

	concentration of structures located in the forested areas of the Black Hills. The population of new residents is growing, especially in Custer, Pennington, and Meade Counties. • In addition to the Black Hills National Forest, there are fire-prone smaller forested areas on the Custer National Forest in Harding County, and BIA Trust and tribal lands on the Pine Ridge Reservation of Oglala Lakota County, and the Rosebud reservation of Todd County. • The wildfire vulnerability analysis associated with the drought vulnerability assessment noted that the counties of Pennington (Very High), Meade, Lawrence, Custer, Fall River, Oglala Lakota, and Todd have the greatest wildfire exposure based on an analysis of historic fire occurrence, WUI housing units, and population. <u>State Facility and Critical infrastructure Impacts</u> • State fire suppression costs have been $2,226,539 annually between 1994-2014 • An analysis conducted as part of the 2015 Drought Mitigation Plan noted a significant increase in fires, acres burned, and suppression costs in drought years. • Risk to state owned/leased buildings and infrastructure includes a number of facilities located in the very high and high vulnerable counties; a more refined vulnerability analysis would be needed to determine site-specific risks. • Other critical infrastructure impacts includes impacts to rural electric infrastructure • Wildfire conditions across South Dakota are likely to worsen in the future due to climate change given that climate projections indicate continued increasing summer temperatures and milder temperatures overall, thus an extended fire season. • Overall Planning Significance: High Significance
Drought (including Extreme Heat)	• Based on historical records notable droughts have occurred somewhere in the state on average about every 12 years, which is equivalent of an 8% chance any given year. • The State returned to severe but short lived drought conditions in 2012-2013 after several wet years. • 13 separate days with a heat-related incident were noted in NCDC 2006-2016; incidents recorded in 2006, 2011, 2012 • These incidents included 1 fatality, ten injuries, $30,000 in property damage (all caused by cattle deaths) and no crop damage • Sector based analysis for 2015 Drought Mitigation Plan included: – Agriculture – Wildland Fire – Water Resources – Wildlife – Tourism – Health and Indirect Societal Effects • According to the USDA Risk Management Agency, insured crop losses to farmers in the State of South Dakota from 2000 to 2014 as a result of drought conditions totaled $2,579,569,105 which equates to an average annual loss of

	$189M. • Livestock impacts were estimated at $162 million for the 2012 drought and $92 million in the 2013 drought. • Water supply and water quality impacts have been greatest along the Missouri River corridor counties. • Quantifying losses to other sectors challenging due to data limitations <u>State Facility and Critical infrastructure Impacts</u> • Direct losses to state owned/leased buildings and infrastructure is expected to be minimal. • State parks in South Dakota are likely to suffer the greatest impacts from drought, particularly those that provide water-based recreational activities. Direct losses to the state can include lost revenue from park access fees and loss in hunting and fishing license revenue. In 2013, there were 20% fewer small game hunting licenses purchased than in 2012 which resulted in a $2 million decrease in revenue. • Other critical infrastructure impacts includes impacts to water facilities, reduced hydroelectric power generation during low flows. • Climate change science indicates changing extremes in precipitation are projected across all seasons, including higher likelihoods of both increasing heavy rain and snow events and more intense droughts. The Northern Plains will remain vulnerable to periodic drought because much of the projected increase in precipitation is expected to occur in the cooler months while increasing temperatures will result in additional evapotranspiration. In regards to temperatures and extreme heat, warmer and more extreme temperatures can exacerbate drought impacts and result in consequences regardless of drought. • Overall Planning Significance: High Significance
Tornado	• South Dakota's location in the northern region of Tornado Alley makes it susceptible to the formation of tornadoes due to warm Gulf air coming in contact with cool Canadian air fronts and dry air systems from the Rocky Mountains. The intersection of these three systems produces thunderstorm conditions that can spawn tornadoes. • According to the National Climatic Data Center, there were 1,711 tornadoes, of which 636 were F1 or higher, in South Dakota between 1950 and 2016 (66 years). Based on this information, the probability that at least one tornado will occur in South Dakota is 100%. • Annualized losses are estimated at nearly $11 million. • Maps of tornado paths indicate a higher likelihood east of the Missouri River and in the southeastern part of the state. • Based on an updated statistical analysis, the vulnerability rankings yield 37 of the 66 counties with a moderate vulnerability ranking, 27 with a high ranking, and 1 with a very high ranking. Lincoln County is the sole county with a very high ranking. • High ranked counties include: Pennington, Lawrence, Meade, Walworth, Hughes, Brown, Spink, Beadle, Tripp, Todd, Charles Mix, Bon Homme, Hutchinson, McCook, Davison, Yankton, Turner, Clay, Union, Minnehaha,

	Lake, Kingsbury, Brookings, Hamlin, Codington, Grant, and Roberts. State Facility and Critical infrastructure Impacts • Risk to state owned/leased buildings and infrastructure is expected to be limited due to the low likelihood of direct impacts. There are four state owned facilities located in Lincoln County, which has the highest vulnerability to tornadoes. • Other critical infrastructure impacts includes impacts to rural electric infrastructure and the potential for direct impacts to local critical facilities. • There presently is not enough data or research to quantify the magnitude of change that climate change may have related to tornado frequency and intensity. • Overall Planning Significance: High Significance
Windstorm	• According to the National Climatic Data Center Storm Events database, there were 7,971 windstorm events (6,901 thunderstorm wind, 1,070 high wind, and 6 strong wind events) in South Dakota between 1955 and July 2016. There were 11 deaths and 136 injuries in this time period. • Total property and crop damage for events between 1993 (when damage figures began being kept) and 2016 is estimated at $151,296,500. • This suggests that South Dakota could experience 272 wind events, $2,605,982 in wind losses, and approximately five injuries each year. • After GIS analysis, the vulnerability rankings concluded that 37 of the 66 counties have a moderate vulnerability ranking, 24 have a high ranking, and 4 have a very high ranking. • Pennington, Meade, Brown, and Minnehaha Counties are all rated very high vulnerability to wind storms. • Highly ranked counties include: Butte, Lawrence, Custer, Oglala Lakota, Todd, Hughes, Walworth, Charles Mix, Davison, Beadle, Bon Homme, Hutchinson, Yankton, turner, Clay, Union, Lincoln, Lake, Moody, Brookings, Hamlin, Codington, Grant, and Roberts Counties. State Facility and Critical infrastructure Impacts • Each very highly ranked county has multiple state-owned critical facilities at risk however direct damages are expected to be minimal if buildings are built to modern codes and standards. • Windstorms can create power outages and exacerbate winter storms. • There presently is not enough data or research to quantify the magnitude of potential change that climate change may have on windstorms. • Overall Planning Significance: Moderate Significance

Hazardous Materials	• Includes both fixed facility and transportation/mobile (air, road, pipeline, rail)
	• Impacts dependent on type of chemical, type of release, mode, area of release, environmental factors
	• U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) statistics indicate 228 reported hazmat incidents (air, highway, water, railway) between 2007 and 2016 that include:
	  o Rail – 7 incidents - $1,790,208 damages
	  o Air – 20 incidents - $0
	  o Highway – 201 incidents - $1,037,522
	  o Water – 0 incidents - $0

	○ 1 incident with a hospitalized injury ○ 1 incident with a non-hospitalized injury ○ No recorded fatalities ○ $2,827,730 in recorded damages ○ Average 25 hazmat incidents/year ○ Average $34,910 in annual damage • 2012 Commodity Flow study in western South Dakota showed that the majority of hazardous materials transported on roadways were flammable liquids • Top ten counties with the most pipelines and potentially higher exposure to an incident are Lincoln, Minnehaha, Brown, Clark, Spink, Butte, Hutchinson, Union, Harding, and Kingsbury; most of these are in the eastern third of the state. • An analysis of Tier II facilities by county yielded that Minnehaha, Pennington, and Harding counties have over 100 facilities. <u>State Facility and Critical infrastructure Impacts</u> • Risk to state owned/leased buildings and infrastructure is expected to be minimal; higher risk to facilities that store hazardous materials, or those facilities close to designated transportation routes • Overall Planning Significance: Moderate Significance
Geologic Hazards – Includes Expansive soils, Subsidence Earthquake Landslide	• Includes expansive soils, subsidence, landslide, mudflow, and earthquake • Extensive expansive soils distribution across state based on US-wide mapping • Subsidence (sinkhole) potential with Karst terrain in Black Hills, southeast • Landslides in Black Hills and Missouri River Bluff counties • Lawrence County landslide along Highway 14A near Cheyenne Crossing in 2012-2013 • Recent earthquakes – January 16, 2012, magnitude 3.0 near Custer/Fall River/Oglala Lakota border – December 12, 2013, magnitude 3.5, south of Colonial Pine Hills – February 7, 2014, magnitude 3.0, Northwest of Platte • Earthquake loss by County using HAZUS resulted in $918M in losses for the 2,500 year probabilistic earthquake <u>State Facility and Critical infrastructure Impacts</u> • Risk to state owned/leased buildings and infrastructure thus far has been limited to state highways. • Other critical infrastructure impacts likely to be limited but could include impacts to bridges, pipelines, water distribution systems, and roads. HAZUS loss modeling did not result in any damage to critical facilities for the 2,500 year event. • Overall Planning Significance: Limited Significance

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Appendix 3A. South Dakota Population and Growth by County

County	2000 Population	2014 Population Estimate	# Change from 2000 to 2014	% Change from 2000 to 2014	2000 Pop Density	2014 Pop Density	Pop. Density Change from 2000-2014	Pop Density Change (%) 2000-2014
Aurora	3,058	2,745	-313	-10.24%	4.3	3.9	-0.4	-9.30%
Beadle	17,023	18,169	1,146	6.73%	13.5	14.4	0.9	6.67%
Bennett	3,574	3,430	-144	-4.03%	3	2.9	-0.1	-3.33%
Bon Homme	7,260	7,023	-237	-3.26%	12.9	12.1	-0.8	-6.20%
Brookings	28,220	33,314	5,094	18.05%	35.5	41.4	5.9	16.62%
Brown	35,460	38,408	2,948	8.31%	20.7	22.2	1.5	7.25%
Brule	5,364	5,309	-55	-1.03%	6.5	6.3	-0.2	-3.08%
Buffalo	2,032	2,077	45	2.21%	4.3	4.3	0	0.00%
Butte	9,094	10,298	1,204	13.24%	4	4.5	0.5	12.50%
Campbell	1,782	1,386	-396	-22.22%	2.4	1.8	-0.6	-25.00%
Charles Mix	9,350	9,287	-63	-0.67%	8.5	8.1	-0.4	-4.71%
Clark	4,143	3,645	-498	-12.02%	4.3	3.8	-0.5	-11.63%
Clay	13,537	13,932	395	2.92%	32.9	33.4	0.5	1.52%
Codington	25,897	27,938	2,041	7.88%	37.7	39	1.3	3.45%
Corson	4,181	4,182	1	0.02%	1.7	1.7	0	0.00%
Custer	7,275	8,445	1,170	16.08%	4.7	5.4	0.7	14.89%
Davison	18,741	19,885	1,144	6.10%	43	45.5	2.5	5.81%
Day	6,267	5,588	-679	-10.83%	6.1	5.1	-1	-16.39%
Deuel	4,498	4,312	-186	-4.14%	7.2	6.8	-0.4	-5.56%

County	2000 Population	2014 Population Estimate	# Change from 2000 to 2014	% Change from 2000 to 2014	2000 Pop Density	2014 Pop Density	Pop. Density Change from 2000-2014	Pop Density Change (%) 2000-2014
Dewey	5,972	5,662	-310	-5.19%	2.6	2.3	-0.3	-11.54%
Douglas	3,458	2,973	-485	-14.03%	8	6.8	-1.2	-15.00%
Edmunds	4,367	3,983	-384	-8.79%	3.8	3.5	-0.3	-7.89%
Fall River	7,453	6,845	-608	-8.16%	4.3	3.9	-0.4	-9.30%
Faulk	2,640	2,357	-283	-10.72%	2.6	2.3	-0.3	-11.54%
Grant	7,847	7,241	-606	-7.72%	11.5	10.5	-1	-8.70%
Gregory	4,792	4,217	-575	-12.00%	4.7	4	-0.7	-14.89%
Haakon	2,196	1,847	-349	-15.89%	1.2	1	-0.2	-16.67%
Hamlin	5,540	5,989	449	8.10%	10.9	11.1	0.2	1.83%
Hand	3,741	3,345	-396	-10.59%	2.6	2.3	-0.3	-11.54%
Hanson	3,139	3,419	280	8.92%	7.2	7.8	0.6	8.33%
Harding	1,353	1,250	-103	-7.61%	0.5	0.5	0	0.00%
Hughes	16,481	17,642	1,161	7.04%	22.2	22	-0.2	-0.90%
Hutchinson	8,075	7,200	-875	-10.84%	9.9	8.8	-1.1	-11.11%
Hyde	1,671	1,396	-275	-16.46%	1.9	1.6	-0.3	-15.79%
Jackson	2,930	3,274	344	11.74%	1.6	1.7	0.1	6.25%
Jerauld	2,295	2,007	-288	-12.55%	4.3	3.8	-0.5	-11.63%
Jones	1,193	975	-218	-18.27%	1.2	1	-0.2	-16.67%
Kingsbury	5,815	5,075	-740	-12.73%	6.9	5.9	-1	-14.49%
Lake	11,276	12,368	1,092	9.68%	20	21.5	1.5	7.50%
Lawrence	21,802	24,657	2,855	13.10%	27.3	30.8	3.5	12.82%
Lincoln	24,131	51,548	27,417	113.62%	41.7	89.1	47.4	113.67%
Lyman	3,895	3,877	-18	-0.46%	2.4	2.3	-0.1	-4.17%

County	2000 Population	2014 Population Estimate	# Change from 2000 to 2014	% Change from 2000 to 2014	2000 Pop Density	2014 Pop Density	Pop. Density Change from 2000-2014	Pop Density Change (%) 2000-2014
Marshall	4,576	4,683	107	2.34%	5.5	4.1	-1.4	-25.45%
McCook	5,832	5,649	-183	-3.14%	10.2	6.4	-3.8	-37.25%
McPherson	2,904	2,429	-475	-16.36%	2.6	4.2	1.6	61.54%
Meade	24,253	26,951	2,698	11.12%	7	7.7	0.7	10.00%
Mellette	2,083	2,100	17	0.82%	1.6	1.6	0	0.00%
Miner	2,884	2,316	-568	-19.69%	5.1	4	-1.1	-21.57%
Minnehaha	148,281	182,882	34,601	23.33%	183.1	224.8	41.7	22.77%
Moody	6,595	6,367	-228	-3.46%	12.7	12.2	-0.5	-3.94%
Oglala Lakota*	12,466	14,218	1,752	14.05%	6	6.8	0.8	13.33%
Pennington	88,565	108,242	19,677	22.22%	31.9	38.9	7	21.94%
Perkins	3,363	3,033	-330	-9.81%	1.2	1	-0.2	-16.67%
Potter	2,693	2,340	-353	-13.11%	3.1	2.6	-0.5	-16.13%
Roberts	10,016	10,374	358	3.57%	9.1	9.1	0	0.00%
Sanborn	2,675	2,336	-339	-12.67%	4.7	4.1	-0.6	-12.77%
Spink	7,454	6,598	-856	-11.48%	5	4.4	-0.6	-12.00%
Stanley	2,772	2,983	211	7.61%	1.9	2	0.1	5.26%
Sully	1,556	1,438	-118	-7.58%	1.5	1.3	-0.2	-13.33%
Todd	9,050	9,882	832	9.19%	6.5	7.1	0.6	9.23%
Tripp	6,430	5,512	-918	-14.28%	4	3.4	-0.6	-15.00%
Turner	8,849	8,272	-577	-6.52%	14.3	13.4	-0.9	-6.29%
Union	12,584	15,029	2,445	19.43%	27.3	32.2	4.9	17.95%
Walworth	5,974	5,511	-463	-7.75%	8.4	7.4	-1	-11.90%

County	2000 Population	2014 Population Estimate	# Change from 2000 to 2014	% Change from 2000 to 2014	2000 Pop Density	2014 Pop Density	Pop. Density Change from 2000-2014	Pop Density Change (%) 2000-2014
Yankton	21,652	22,684	1,032	4.77%	41.5	42.6	1.1	2.65%
Ziebach	2,519	2,826	307	12.19%	1.3	1.4	0.1	7.69%

Source: Census Bureau; *Formerly Shannon County prior to March 2015

Appendix 3B. HAZUS 100 Year Flood Summary Detail

County Name	Population	Building Damage Count	Building Damage Loss ($K)	Building Exposure ($K)	Percent Building Damage	Contents Damage Loss ($K)	Contents Exposure ($K)	Percent Contents Loss	Total Direct Econ Bldg Loss ($K)	Per Capita Loss ($)	Short Term Shelter Needs	Displaced Population
Aurora	2,867	17	3,914	192,008	2.0%	5,561	124,059	4.5%	10,125	3,532	101	481
Beadle	15,878	6	3,673	1,140,956	0.3%	6,000	785,184	0.8%	10,393	655	64	387
Bennett	3,393	0	1,165	121,952	1.0%	1,808	77,157	2.3%	3,145	927	2	71
Bon Homme	7,079	7	1,815	439,005	0.4%	1,870	289,434	48.9%	3,828	541	37	117
Brookings	29,668	7	4,563	1,762,160	0.3%	9,953	1,183,412	0.8%	15,476	522	383	943
Brown	35,154	71	16,502	2,361,052	0.7%	22,083	1,615,566	1.4%	40,502	1,152	854	1,785
Brule	5,205	1	1,423	359,042	0.4%	1,813	242,365	0.7%	3,498	672	19	151
Buffalo	2,142	1	645	59,844	1.1%	631	41,010	1.5%	1,347	629	30	79
Butte	9,593	24	9,890	424,525	2.3%	10,891	273,830	4.0%	21,428	2,234	271	892
Campbell	1,352	37	3,393	106,582	3.2%	5,017	71,024	7.1%	8,813	6,518	124	383
Charles Mix	8,906	4	4,020	542,879	0.7%	5,337	385,775	1.4%	9,842	1,105	46	232
Clark	3,436	2	1,208	253,750	0.5%	1,880	172,779	1.1%	3,328	969	45	159
Clay	13,605	18	2,952	787,934	0.4%	2,268	498,107	0.5%	5,327	392	88	248
Codington	26,317	221	28,917	1,684,272	1.7%	48,403	1,230,471	3.9%	81,843	3,110	2,301	3,027
Corson	4,136	16	2,089	137,273	1.5%	1,711	88,402	1.9%	3,894	941	285	446

County Name	Population	Building Damage Count	Building Damage Loss ($K)	Building Exposure ($K)	Percent Building Damage	Contents Damage Loss ($K)	Contents Exposure ($K)	Percent Contents Loss	Total Direct Econ Bldg Loss ($K)	Per Capita Loss ($)	Short Term Shelter Needs	Displaced Population
Custer	7,811	6	5,092	462,408	1.1%	10,476	282,818	3.7%	16,746	2,144	44	257
Davison	18,931	24	6,417	1,159,549	0.6%	6,297	772,127	0.8%	13,185	696	216	530
Day	5,526	5	1,649	484,855	0.3%	1,386	307,022	0.5%	3,187	577	10	157
Deuel	4,276	2	1,386	287,842	0.5%	2,256	184,891	1.2%	3,922	917	34	154
Dewey	5,931	3	1,532	185,425	0.8%	981	115,356	0.9%	2,557	431	31	166
Douglas	2,945	5	984	191,287	0.5%	1,163	136,333	0.9%	2,342	795	14	152
Edmunds	4,034	30	2,718	274,727	1.0%	2,526	177,453	1.4%	5,461	1,354	156	293
Fall River	7,145	92	14,007	434,042	3.2%	20,735	275,507	7.5%	36,379	5,092	250	525
Faulk	2,255	4	1,275	162,503	0.8%	1,592	111,483	1.4%	3,056	1,355	94	179
Grant	7,101	22	4,422	488,046	0.9%	4,652	322,886	1.4%	9,592	1,351	97	415
Gregory	4,084	0	474	277,213	0.2%	254	186,244	0.1%	731	179	-	44
Haakon	1,819	13	3,761	146,783	2.6%	5,756	109,343	5.3%	10,151	5,581	78	303
Hamlin	5,660	18	5,398	388,992	1.4%	9,963	250,564	4.0%	16,441	2,905	31	387
Hand	3,274	9	2,083	296,103	0.7%	1,931	202,183	1.0%	4,161	1,271	39	197
Hanson	3,609	0	1,368	175,231	0.8%	1,029	111,737	0.9%	2,473	685	3	94
Harding	1,145	0	504	82,331	0.6%	516	54,129	1.0%	1,045	913	2	43
Hughes	16,746	7	3,195	1,124,701	0.3%	5,319	780,813	0.7%	8,871	530	297	611
Hutchinson	7,250	29	5,799	503,541	1.2%	9,436	358,305	2.6%	16,001	2,207	646	957

County Name	Population	Building Damage Count	Building Damage Loss ($K)	Building Exposure ($K)	Percent Building Damage	Contents Damage Loss ($K)	Contents Exposure ($K)	Percent Contents Loss	Total Direct Econ Bldg Loss ($K)	Per Capita Loss ($)	Short Term Shelter Needs	Displaced Population
Hyde	1,424	0	292	104,891	0.3%	370	71,114	0.5%	709	498	-	39
Jackson	2,711	0	702	117,513	0.6%	723	75,716	1.0%	1,445	533	3	69
Jerauld	1,982	0	591	173,814	0.3%	833	120,597	0.7%	1,534	774	8	77
Jones	1,024	1	288	70,695	0.4%	243	48,339	0.5%	551	538	-	17
Kingsbury	5,394	0	1,366	397,000	0.3%	2,080	265,171	0.8%	3,672	681	48	281
Lake	11,693	72	8,740	802,854	1.1%	11,306	543,394	2.1%	20,840	1,782	664	1,128
Lawrence	23,524	72	20,631	1,420,311	1.5%	28,237	943,068	3.0%	50,103	2,130	504	979
Lincoln	39,713	26	7,275	1,526,898	0.5%	6,826	1,004,113	0.7%	14,514	365	210	524
Lyman	3,811	13	3,267	210,965	1.5%	3,329	142,040	2.3%	6,876	1,804	38	145
Marshall	4,320	0	1,062	345,298	0.3%	1,052	224,483	0.5%	2,223	515	7	143
McCook	5,671	18	3,257	374,493	0.9%	2,680	242,410	1.1%	6,096	1,075	65	252
McPherson	2,480	0	628	186,748	0.3%	815	131,351	0.6%	1,545	623	4	95
Meade	23,989	8	4,808	1,269,102	0.4%	6,458	789,678	0.8%	11,765	490	106	469
Mellette	1,982	14	1,501	79,167	1.9%	817	50,927	1.6%	2,331	1,176	109	223
Miner	2,435	9	1,527	180,686	0.8%	1,685	119,490	1.4%	3,363	1,381	66	159
Minnehaha	179,180	719	162,527	10,171,077	1.6%	252,358	7,016,387	3.6%	432,484	2,414	6,159	7,482
Moody	6,414	2	2,072	392,198	0.5%	1,949	248,960	0.8%	4,220	658	9	216

County Name	Population	Building Damage Count	Building Damage Loss ($K)	Building Exposure ($K)	Percent Building Damage	Contents Damage Loss ($K)	Contents Exposure ($K)	Percent Contents Loss	Total Direct Econ Bldg Loss ($K)	Per Capita Loss ($)	Short Term Shelter Needs	Displaced Population
Pennington	98,533	88	13,624	5,606,639	0.2%	14,685	3,848,985	0.4%	29,402	298	724	1,379
Perkins	2,900	0	1,293	210,653	0.6%	982	145,019	0.7%	2,339	807	-	76
Potter	2,123	0	537	255,587	0.2%	781	204,883	0.4%	1,416	667	1	44
Roberts	9,851	8	2,903	612,941	0.5%	3,991	401,423	1.0%	7,273	738	36	320
Sanborn	2,447	0	1,121	166,987	0.7%	1,121	107,751	1.0%	2,400	981	3	142
Shannon*	13,637	34	8,180	321,592	2.5%	11,173	218,211	5.1%	20,430	1,498	492	1,214
Spink	6,664	15	6,474	484,402	1.3%	7,554	312,052	2.4%	14,644	2,197	217	572
Stanley	2,703	131	14,974	162,796	9.2%	11,356	103,953	10.9%	26,644	9,857	340	666
Sully	1,356	0	502	114,641	0.4%	456	74,970	0.6%	1,016	749	1	42
Todd	10,167	9	2,227	277,272	0.8%	3,458	185,432	1.9%	5,723	563	105	314
Tripp	5,681	31	3,470	392,821	0.9%	3,446	274,410	1.3%	7,248	1,276	86	265
Turner	8,366	12	5,659	606,311	0.9%	7,748	409,118	1.9%	14,191	1,696	39	391
Union	14,131	867	119,836	1,031,826	11.6%	203,473	800,039	25.4%	349,991	24,768	3,451	4,428
Walworth	5,238	0	780	393,371	0.2%	786	263,677	0.3%	1,632	312	-	63
Yankton	21,835	713	81,492	1,464,392	5.6%	105,103	1,081,598	9.7%	193,250	8,850	2,614	3,328
Ziebach	2,542	8	1,403	66,932	2.1%	749	39,623	1.9%	2,158	849	75	191
TOTAL	**804,194**	**3,571**	**633,242**	**47,491,686**	**1.3%**	**910,117**	**32,326,151**	**3%**	**1,623,118**	**126,423**	**22,876**	**40,598**

Source: HAZUS-MH MR4; *County name changed to Oglala Lakota in 2015

Appendix 3C. South Dakota Flood Insurance Policies and Losses by County

County	# of Policies	Total Coverage	Total Premium	Total Claims Since 1978	Total Paid Since 1978
Aurora	7	$492,300	$4,059	0	$0
Beadle	15	$3,199,100	$7,045	21	$327,076
Bon Homme	3	$770,000	$1,110	0	$0
Brookings	151	$18,224,100	$127,778	83	$829,743
Brown	277	$51,238,300	$243,082	483	$3,283,454
Brule	0	$0	$0	2	$142,021
Butte	50	$6,336,300	$32,696	12	$11,834
Charles Mix	5	$494,300	$3,189	6	$326,230
Clark	12	$1,565,000	$6,919	11	$184,850
Clay	11	$3,330,000	$4,378	12	$50,954
Codington	524	$97,426,900	$403,212	425	$5,749,018
Corson	1	$200,000	$939	0	$0
Custer	85	$14,825,300	$58,898	42	$560,642
Davison	29	$5,664,500	$17,662	13	$85,072
Day	31	$4,943,600	$35,020	252	$4,011,874
Deuel	2	$288,000	$1,840	1	$3,758
Dewey	1	$250,000	$835	0	$0
Douglas	0	$0	$0	1	$520
Edmunds	2	$700,000	$827	4	$2,980
Fall River	22	$2,857,500	$23,593	1	$25
Faulk	0	$0	$0	2	$5,206
Grant	20	$4,546,100	$26,190	26	$226,226
Gregory	1	$350,000	$373	2	$161,998
Haakon	13	$1,195,000	$11,684	2	$0
Hamlin	57	$12,326,900	$35,550	347	$4,201,281
Hand	6	$1,429,300	$4,779	3	$76,119
Hanson	6	$846,600	$6,570	3	$30,480
Hughes	70	$15,088,500	$60,370	81	$693,587
Hutchinson	13	$1,576,300	$8,202	9	$95,129
Hyde	0	$0	$0	1	$0
Jerauld	1	$350,000	$412	0	$0

County	# of Policies	Total Coverage	Total Premium	Total Claims Since 1978	Total Paid Since 1978
Kingsbury	2	$430,000	$1,275	33	$365,002
Lake	169	$30,609,500	$121,452	152	$1,419,607
Lawrence	197	$40,278,900	$204,428	38	$267,432
Lincoln	1,336	$389,092,500	$1,337,679	177	$5,233,428
Lyman	8	$775,200	$14,217	3	$117,254
Marshall	3	$910,000	$1,133	12	$144,192
McCook	23	$3,568,600	$22,884	11	$41,756
Meade	121	$19,214,000	$122,272	20	$42,863
Miner	1	$350,000	$370	0	$0
Minnehaha	132	$24,017,700	$108,723	132	$906,393
Moody	24	$3,133,500	$30,940	58	$455,782
Pennington	540	$121,375,700	$500,596	116	$308,246
Potter	54	$10,584,900	$46,510	61	$634,544
Roberts	3	$1,420,000	$1,887	14	$46,953
Sanborn	36	$6,109,500	$27,847	69	$921,480
Spink	125	$31,329,800	$110,361	113	$2,555,204
Stanley	1	$350,000	$412	5	$22,793
Sully	6	$639,900	$5,997	2	$1,362
Todd	2	$450,000	$2,087	0	$0
Turner	13	$1,547,600	$9,063	12	$77,189
Union	403	$119,134,300	$275,463	420	$5,076,498
Yankton	69	$15,670,400	$54,482	48	$353,891
Ziebach	1	$210,000	$348	3	$3,427
State Total:	**4,684**	**$1,071,715,900**	**$4,127,638**	**3,344**	**$40,055,373**

Source: FEMA NFIP Policy and Claims Report for South Dakota; produced June, 2016.

Appendix 3D Vulnerability Methodology

This appendix includes more details for the methodology for the vulnerability analysis of winter storms, windstorm and tornadoes.

Building Exposure— One aspect of vulnerability is considering assets exposed and potentially vulnerable to loss. A total building exposure by county was derived from HAZUS V3.1 (residential, commercial, industrial, agricultural, religion, government, and education) which is based on Census 2010 statistics. In the 2016 update the total exposure by county was extracted from HAZUS. For the 2016 HIRA update, the classification scheme changed for Building Exposure category to refine total rank by county (from equal interval to natural breaks). The total range of building exposure ($114,735-$19,134,394) was analyzed to find natural breaks in the data. The ranges were numbered 1 through 10 in ascending order as noted in the following table.

Table 1 Building Exposure Ratings

Building Exposure ($)	Rating
114,735-2,016,700	1
2,016,701-3,918,666	2
3,918,667-5,820,632	3
5,820,633-7,722,598	4
7,722,599-9,624,564	5
9,624,564-11,526,530	6
11,526,531-13,428,496	7
13,428,497-15,330,462	8
15,330,463-17,232,428	9
17,232,429-19,134,394	10

Population Density—Population density is determined by dividing a county's population by its land area. This section is based on the 2011 U.S. Census Bureau population estimates and the land area reported in the 2010 Census. For the 2016 update, the range of population densities (0.5 to 212.8) was divided into 10 roughly equal ranges as shown in Table 2. The ranges were numbered 1 through 10 in ascending order. For the 2016 update, the classification scheme changed for the Population Density category to refine total rank by county (from equal interval to natural breaks). The total range of population density (.5-203.7) was analyzed to find natural breaks in the data.

Table 2 Population Density Ratings

Population Density	Rating
Density	**Rating**
.5-23	1
23.1-45.5	2
45.6-68.1	3
68.2-90.7	4
90.8-113.3	5
113.4-135.9	6
136-158.5	7
158.6-181.1	8
181.2-203.7	9

These building exposure and population density ratings were components of the vulnerability analyses for windstorm, tornado and winter storm. Windstorm, tornado, and winter storm vulnerability methodologies are described below and include the tables used to determine the summary vulnerability rankings.

Windstorm

Prior Events—This rating is based on the number of past windstorm events experienced by each county between January 1955 and August 2016 according to data from the National Climatic Data Center's Storm Events database (a compilation of storm data from the National Weather Service). For the purposes of this plan, a windstorm event is considered thunderstorm winds or high winds as identified in the National Climatic Data Center's database. In addition, particularly severe events (those with a speed of 70 knots or higher or that caused monetary damage, fatalities, or injuries) were also assessed. (see the description of the windstorm events that affect South Dakota in the Windstorm Hazard Profile).

To develop the prior event rating, the total range of past occurrences was divided into 10 roughly equal ranges as shown in Table 3 and Table 4. The ranges were numbered 1 through 10 in ascending order.

Table 3 Windstorm Prior Event Ratings

# of Past Occurrences	Rating
47-88	1
89-128	2
129-167	3
168-207	4
208-247	5
248-287	6
289-328	7
329-368	8
369-408	9
409-448	10

Table 4 Windstorm Prior Event Ratings (Wind speed ≥70 kts)

# of Past Occurrences	Rating
6-12	1
13-20	2
21-27	3
28-34	4
35-41	5
42-48	6
49-55	7
56-62	8
63-69	9
70-76	10

After rating each of the counties on the factors described above, each factor was separately added with building exposure ratings and population density ratings to produce a county-level vulnerability rating. The highest possible total vulnerability rating was 30. The total range of vulnerability was divided into three equal ranges as shown in Table 5. The ranges were assigned a corresponding level of windstorm vulnerability: moderate, high, and very high.

Table 5 Windstorm Vulnerability

Windstorm Vulnerability Range	Windstorm Vulnerability
3-11	Moderate
12-21	High
22-30	Very High

This vulnerability was assigned to each county considering both total windstorm events and those with a wind speed of 70 knots or greater, or that caused damage, injuries, or fatalities.

The table below provides details on each counties' individual ratings for each factor.

Table 6 Windstorm Vulnerability Calculations

County	Total Events	Event Rating	Total Events > 70 kts	Event Rating > 70 kts	Building Exposure	Rating (Natural Breaks)	Population Density	Pop Density Rating (Natural Breaks)	Vulnerability Rating	Vulnerability Category	Vuln. > 70 kts	Vuln>70kts Cateogry
Aurora	66	1	26	3	$343,330	3	3.9	3	7	Moderate	9	Moderate
Beadle	212	5	54	7	$1,950,510	7	14.4	7	19	High	21	High
Bennett	97	2	17	2	$247,449	2	2.9	3	7	Moderate	7	Moderate
Bon Homme	96	2	33	4	$684,668	5	12.1	6	13	High	15	High
Brookings	131	3	50	7	$3,232,047	8	41.4	8	19	High	23	Very High
Brown	249	6	30	4	$4,022,770	8	22.2	8	22	Very High	20	High
Brule	116	2	20	2	$598,841	4	6.3	4	10	Moderate	10	Moderate
Buffalo	69	1	7	1	$114,735	1	4.3	3	5	Moderate	5	Moderate
Butte	233	5	45	6	$859,242	5	4.5	4	14	High	15	High
Campbell	91	2	9	1	$211,527	2	1.8	2	6	Moderate	5	Moderate
Charles Mix	131	3	43	6	$979,078	6	8.1	5	14	High	17	High
Clark	90	2	17	2	$461,331	4	3.8	3	9	Moderate	9	Moderate
Clay	100	2	34	4	$1,352,347	6	33.4	8	16	High	18	High
Codington	131	3	18	2	$3,141,546	8	39.0	8	19	High	18	High
Corson	179	4	21	3	$261,189	2	1.7	1	7	Moderate	6	Moderate
Custer	175	4	24	3	$1,059,574	6	5.4	4	14	High	13	High
Davison	153	3	36	5	$2,033,945	7	45.5	9	19	High	21	High
Day	127	2	33	4	$739,380	5	5.1	4	11	Moderate	13	High
Deuel	84	1	11	1	$557,548	4	6.8	5	10	Moderate	10	Moderate
Dewey	127	2	24	3	$326,693	3	2.3	2	7	Moderate	8	Moderate
Douglas	57	1	19	2	$410,033	3	6.8	5	9	Moderate	10	Moderate
Edmunds	137	3	16	2	$428,157	4	3.5	3	10	Moderate	9	Moderate
Fall River	108	2	23	3	$772,078	5	3.9	3	10	Moderate	11	Moderate
Faulk	102	2	20	2	$319,966	3	2.3	2	7	Moderate	7	Moderate
Grant	70	1	15	2	$852,422	5	10.5	6	12	High	13	High
Gregory	71	1	22	3	$499,638	4	4.0	3	8	Moderate	10	Moderate
Haakon	192	4	33	4	$304,961	3	1.0	1	8	Moderate	8	Moderate
Hamlin	73	1	22	3	$657,563	5	11.1	6	12	High	14	High
Hand	109	2	10	1	$489,795	4	2.3	2	8	Moderate	7	Moderate
Hanson	76	1	27	3	$375,684	3	7.8	5	9	Moderate	11	Moderate
Harding	271	6	40	5	$134,729	1	0.5	1	8	Moderate	7	Moderate
Hughes	193	4	31	4	$2,011,351	7	22.0	7	18	High	18	High
Hutchinson	101	2	34	4	$921,743	6	8.8	5	13	High	15	High
Hyde	74	1	6	1	$174,088	2	1.6	1	4	Moderate	4	Moderate

County	Total Events	Event Rating	Total Events > 70 kts	Event Rating > 70 kts	Building Exposure	Rating (Natural Breaks)	Population Density	Pop Density Rating (Natural Breaks)	Vulnerability Rating	Vulnerability Category	Vuln. > 70 kts	Vuln>70kts Cateogry
Jackson	162	3	36	5	$279,813	2	1.7	1	6	Moderate	8	Moderate
Jerauld	65	1	23	3	$292,480	2	3.8	3	6	Moderate	8	Moderate
Jones	80	1	6	1	$154,067	1	1.0	1	3	Moderate	3	Moderate
Kingsbury	107	2	37	5	$718,391	5	5.9	4	11	Moderate	14	High
Lake	117	2	44	6	$1,464,020	7	21.5	7	16	High	20	High
Lawrence	47	1	7	1	$2,942,654	8	30.8	8	17	High	17	High
Lincoln	138	3	44	6	$4,858,425	9	89.1	9	21	High	24	Very High
Lyman	152	3	17	2	$387,530	3	2.3	2	8	Moderate	7	Moderate
Marshall	93	2	18	2	$613,226	4	6.4	5	11	Moderate	11	Moderate
McCook	97	2	37	5	$337,182	3	4.2	3	8	Moderate	11	Moderate
McPherson	80	1	9	1	$569,412	4	4.1	3	8	Moderate	8	Moderate
Meade	439	10	72	10	$2,374,927	7	7.7	5	22	Very High	22	Very High
Mellette	87	1	17	2	$145,156	1	1.6	1	3	Moderate	4	Moderate
Miner	76	1	26	3	$300,577	2	4.0	3	6	Moderate	8	Moderate
Minnehaha	257	6	68	9	$19,134,385	10	224.8	10	26	Very High	29	Very High
Moody	73	1	32	4	$752,929	5	12.2	6	12	High	15	High
Oglala Lakota	165	3	30	4	$623,369	5	6.8	5	13	High	14	High
Pennington	402	9	61	8	$11,128,870	10	38.9	8	27	Very High	26	Very High
Perkins	223	5	46	6	$349,270	3	1.0	1	9	Moderate	10	Moderate
Potter	95	2	10	1	$405,402	3	2.6	2	7	Moderate	6	Moderate
Roberts	83	1	14	2	$993,542	6	9.1	6	13	High	14	High
Sanborn	80	1	27	3	$331,251	3	4.1	3	7	Moderate	9	Moderate
Spink	130	3	34	4	$762,242	5	4.4	3	11	Moderate	12	High
Stanley	133	3	19	2	$316,125	3	2.0	2	8	Moderate	7	Moderate
Sully	103	2	13	2	$213,590	2	1.3	1	5	Moderate	5	Moderate
Todd	154	3	36	5	$584,882	4	7.1	5	12	High	14	High
Tripp	156	3	29	4	$660,351	5	3.4	3	11	Moderate	12	High
Turner	96	2	34	4	$1,047,334	6	13.4	6	14	High	16	High
Union	106	2	35	5	$1,866,198	7	32.2	8	17	High	20	High
Walworth	130	3	18	2	$664,408	5	7.4	5	13	High	12	High
Yankton	128	2	42	6	$2,630,709	8	42.6	8	18	High	22	Very High
Ziebach	158	3	30	4	$134,376	1	1.4	1	5	Moderate	6	Moderate

Tornado

Prior Events—This rating is based on the number of past tornadoes experienced by each county between January 1950 and August 2016 according to data from the National Climatic Data Center's Storm Events database (a compilation of storm data from the National Weather Service). Tornadoes reported in the database are in segments. So, the number of past occurrences is really a reflection of the number of past tornado segments. To develop the prior event rating, the total range of past occurrences was divided into 10 roughly equal ranges as shown in Table 7. The ranges were numbered 1 through 10 in ascending order.

Table 7 Tornadoes Prior Event Ratings

# of Past Occurrences	Rating
6-12	1
13-20	2
21-28	3
29-36	4
37-44	5
45-52	6
53-60	7
61-68	8
69-76	9
77-84	10

In addition to the total events tabulation, a prior event rating was established for each county based on the number of F1 or greater tornadoes in the county, the number of tornadoes that caused death or injury, or the number of tornadoes with recorded financial damage. This was used to help determine if there are areas of particular vulnerability to more severe tornado events. The increased the overall number of tornadoes analyzed, as well as total damages. Total damages were inflated to $2012 dollars instead of year-of-event dollars. The information was drawn from the NCDC database and may not account for new methodologies in assessing a tornado's rating. This information was also divided into ten roughly equal ranges and is displayed in the table below.

Table 8 Tornadoes of at least F1 Rating Prior Event Ratings

# of Past Occurrences	Rating
0-2	1
3-5	2
6-8	3
9-11	4
12-14	5
15-17	6
18-20	7
21-23	8
24-26	9
27-29	10

Past Tornado Damage— This rating is based on the property damage for the tornadoes that occurred in South Dakota between 1950 and 2016 as reported in the National Climatic Data Center's Storm Events database. This damage was presented in actual values for the year the events occurred. To more accurately compare the damage values, they were converted to 2016 dollars using Consumer Price Index conversion factors published by Oregon State University (this is similar to the methodology used in FEMA's inflation calculator in its Benefits Cost Analysis Toolkit). The inflated values suggest that the state had $713,216,263 (2016 dollars) in tornado damage between 1950 and 2016, which averages out to approximately $ 10,806,307 per year. The total range of past tornado damage ($143,138-$160,034,605) was divided into 10 roughly equal ranges (16,000,000) as shown in Table 9. The ranges were numbered 1 through 10 in ascending order.

Table 9 Past Tornado Damage Ratings

Damages ($)	Rating
0-16,000,000	1
16,000,001-32,000,000	2
32,000,001-51,000,000	3
51,000,001-67,000,000	4
67,000,001-83,000,000	5
83,000,001-99,000,000	6
99,000,001-115,000,000	7
115,000,001-131,000,000	8
131,000,001-147,000,000	9
147,000,001-163,000,000	10

Table 10 Annualized Tornado Losses in South Dakota

County	Total Damages	Total Damages (2016 dollars)	Annualized Losses
Aurora	$513,026	$521,234	$7,897
Beadle	$21,896,842	$22,247,191	$337,079
Bennett	$3,331,730	$3,385,038	$51,288
Bon Homme	$4,922,708	$5,001,471	$75,780
Brookings	$5,021,762	$5,102,110	$77,305
Brown	$14,326,236	$14,555,455	$220,537
Brule	$12,031,035	$12,223,531	$185,205
Buffalo	$40,991,510	$41,647,374	$631,021
Butte	$2,083,622	$2,116,960	$32,075
Campbell	$3,142,331	$3,192,609	$48,373
Charles Mix	$8,485,126	$8,620,888	$130,620

Clark	$11,402,416	$11,584,854	$175,528
Clay	$5,032,445	$5,112,964	$77,469
Codington	$21,527,349	$21,871,786	$331,391
Corson	$2,178,746	$2,213,606	$33,539
Custer	$380,726	$386,818	$5,861
Davison	$20,572,249	$20,901,405	$316,688
Day	$8,213,528	$8,344,944	$126,439
Deuel	$189,694	$192,729	$2,920
Dewey	$561,240	$570,220	$8,640
Douglas	$3,320,104	$3,373,226	$51,109
Edmunds	$140,885	$143,139	$2,169
Fall River	$2,382,926	$2,421,053	$36,683
Faulk	$454,717	$461,992	$7,000
Grant	$867,345	$881,222	$13,352
Gregory	$22,208,895	$22,564,237	$341,882
Haakon	$931,208	$946,107	$14,335
Hamlin	$773,837	$786,218	$11,912
Hand	$19,966,516	$20,285,980	$307,363
Hanson	$2,019,246	$2,051,553	$31,084
Harding	$224,586	$228,179	$3,457
Hughes	$13,075,448	$13,284,655	$201,283
Hutchinson	$1,997,638	$2,029,601	$30,752
Hyde	$270,857	$275,190	$4,170
Jackson	$682,019	$692,932	$10,499
Jerauld	$5,728,852	$5,820,513	$88,190
Jones	$142,378	$144,656	$2,192
Kingsbury	$12,048,831	$12,241,613	$185,479
Lake	$5,907,212	$6,001,728	$90,935
Lawrence	$2,022,929	$2,055,296	$31,141
Lincoln	$157,514,376	$160,034,606	$2,424,767
Lyman	$728,615	$740,273	$11,216
Marshall	$4,530,233	$4,602,717	$69,738
McCook	$44,441,499	$45,152,563	$684,130
McPherson	$13,099,466	$13,309,058	$201,652
Meade	$6,865,296	$6,975,140	$105,684
Mellette	$1,343,958	$1,365,461	$20,689
Miner	$5,017,096	$5,097,369	$77,233
Minnehaha	$27,589,456	$28,030,888	$424,710

Moody	$827,037	$840,270	$12,731
Oglala Lakota	$4,926,733	$5,005,560	$75,842
Pennington	$18,114,266	$18,404,094	$278,850
Perkins	$2,530,977	$2,571,473	$38,962
Potter	$8,462,831	$8,598,236	$130,276
Roberts	$9,488,190	$9,640,001	$146,061
Sanborn	$1,049,842	$1,066,640	$16,161
Spink	$1,245,846	$1,265,780	$19,178
Stanley	$378,946	$385,009	$5,833
Sully	$320,096	$325,217	$4,928
Todd	$2,248,569	$2,284,546	$34,614
Tripp	$18,830,914	$19,132,208	$289,882
Turner	$51,471,078	$52,294,616	$792,343
Union	$5,030,606	$5,111,096	$77,441
Walworth	$3,350,528	$3,404,137	$51,578
Yankton	$28,935,743	$29,398,715	$445,435
Ziebach	$1,671,568	$1,698,313	$25,732

After rating each of the counties on the factors described above, each factor was separately added with damage ratings, building exposure ratings and population density ratings to produce a county-level vulnerability rating. The highest possible total vulnerability rating was 40. The total range of vulnerability was divided into three equal ranges as shown in Table 11. The ranges were assigned a corresponding level of tornado vulnerability: moderate, high, and very high. The vulnerability scale begins at moderate as every county has some degree of vulnerability.

Table 11 Tornado Vulnerability

Tornado Vulnerability Range	Tornado Vulnerability
1-13	Moderate
14-27	High
28-40	Very High

The table below provides details on each counties' individual ratings for each factor.

Table 12 Tornado Vulnerability Calculations

County	Total Events	Prior Event Rating	Damage Rating	Total events >F1	Prior Event Rating > F1	Building Exposure	Building Exposure Rating (Natural Breaks)	Population Density	Pop Density Rating (Natural Breaks)	Vuln. Rating	Vuln. Category	Vuln. ≥F1	Vuln. ≥F1 Category
Aurora	14	2	1	4	2	$343,330	3	3.9	3	9	Moderate	9	Moderate
Beadle	35	4	2	17	6	$1,950,510	7	14.4	7	20	High	22	High
Bennett	24	3	1	11	4	$247,449	2	2.9	3	9	Moderate	10	Moderate
Bon Homme	23	3	1	15	6	$684,668	5	12.1	6	15	High	18	High
Brookings	26	3	1	10	4	$3,232,047	8	41.4	8	20	High	21	High
Brown	77	10	1	29	10	$4,022,770	8	22.2	8	27	High	27	High
Brule	27	3	1	12	5	$598,841	4	6.3	4	12	Moderate	14	High
Buffalo	15	2	3	3	2	$114,735	1	4.3	3	9	Moderate	9	Moderate
Butte	14	2	1	10	4	$859,242	5	4.5	4	12	Moderate	14	High
Campbell	13	2	1	8	3	$211,527	2	1.8	2	7	Moderate	8	Moderate
Charles Mix	43	5	1	25	9	$979,078	6	8.1	5	17	High	21	High
Clark	28	3	1	16	6	$461,331	4	3.8	3	11	Moderate	14	High
Clay	30	4	1	14	5	$1,352,347	6	33.4	8	19	High	20	High
Codington	29	4	2	10	4	$3,141,546	8	39	8	22	High	22	High
Corson	22	3	1	4	2	$261,189	2	1.7	1	7	Moderate	6	Moderate
Custer	11	1	1	9	4	$1,059,574	6	5.4	4	12	Moderate	15	High
Davison	25	3	2	13	5	$2,033,945	7	45.5	9	21	High	23	High
Day	23	3	1	7	3	$739,380	5	5.1	4	13	Moderate	13	Moderate
Deuel	19	2	1	7	3	$557,548	4	6.8	5	12	Moderate	13	Moderate
Dewey	27	3	1	8	3	$326,693	3	2.3	2	9	Moderate	9	Moderate
Douglas	25	3	1	9	4	$410,033	3	6.8	5	12	Moderate	13	Moderate
Edmunds	19	2	1	8	3	$428,157	4	3.5	3	10	Moderate	11	Moderate
Fall River	29	4	1	15	6	$772,078	5	3.9	3	13	Moderate	15	High
Faulk	18	2	1	8	3	$319,966	3	2.3	2	8	Moderate	9	Moderate
Grant	17	2	1	8	3	$852,422	5	10.5	6	14	High	15	High
Gregory	22	3	2	9	4	$499,638	4	4	3	12	Moderate	13	Moderate
Haakon	23	3	1	12	5	$304,961	3	1	1	8	Moderate	10	Moderate
Hamlin	18	2	1	7	3	$657,563	5	11.1	6	14	High	15	High
Hand	32	4	2	13	5	$489,795	4	2.3	2	12	Moderate	13	Moderate
Hanson	18	2	1	11	4	$375,684	3	7.8	5	11	Moderate	13	Moderate
Harding	18	2	1	6	3	$134,729	1	0.5	1	5	Moderate	6	Moderate

County	Total Events	Prior Event Rating	Damage Rating	Total events >F1	Prior Event Rating > F1	Building Exposure	Building Exposure Rating (Natural Breaks)	Population Density	Pop Density Rating (Natural Breaks)	Vuln. Rating	Vuln. Category	Vuln. ≥F1	Vuln. ≥F1 Category
Hughes	12	1	1	6	3	$2,011,351	7	22	7	16	High	18	High
Hutchinson	43	5	1	20	7	$921,743	6	8.8	5	17	High	19	High
Hyde	12	1	1	3	2	$174,088	2	1.6	1	5	Moderate	6	Moderate
Jackson	19	2	1	11	4	$279,813	2	1.7	1	6	Moderate	8	Moderate
Jerauld	14	2	1	8	3	$292,480	2	3.8	3	8	Moderate	9	Moderate
Jones	6	1	1	3	2	$154,067	1	1	1	4	Moderate	5	Moderate
Kingsbury	41	5	1	16	6	$718,391	5	5.9	4	15	High	16	High
Lake	20	2	1	13	5	$1,464,020	7	21.5	7	17	High	20	High
Lawrence	17	2	1	11	4	$2,942,654	8	30.8	8	19	High	21	High
Lincoln	51	6	10	21	8	$4,858,425	9	89.1	9	34	Very High	36	Very High
Lyman	36	4	1	16	6	$387,530	3	2.3	2	10	Moderate	12	Moderate
Marshall	18	2	1	10	4	$613,226	4	6.4	5	12	Moderate	14	High
McCook	39	5	3	23	8	$337,182	3	4.2	3	14	High	17	High
McPherson	24	3	1	11	4	$569,412	4	4.1	3	11	Moderate	12	Moderate
Meade	41	5	1	21	8	$2,374,927	7	7.7	5	18	High	21	High
Mellette	12	1	1	5	2	$145,156	1	1.6	1	4	Moderate	5	Moderate
Miner	33	4	1	16	6	$300,577	2	4	3	10	Moderate	12	Moderate
Minnehaha	40	5	2	21	8	$19,134,385	10	224.8	10	27	High	30	Very High
Moody	10	1	1	6	3	$752,929	5	12.2	6	13	Moderate	15	High
Oglala Lakota	20	2	1	10	4	$623,369	5	6.8	5	13	Moderate	15	High
Pennington	44	5	2	19	7	$11,128,870	10	38.9	8	25	High	27	High
Perkins	39	5	1	15	6	$349,270	3	1	1	10	Moderate	11	Moderate
Potter	20	2	1	12	5	$405,402	3	2.6	2	8	Moderate	11	Moderate
Roberts	23	3	1	15	6	$993,542	6	9.1	6	16	High	19	High
Sanborn	21	3	1	9	4	$331,251	3	4.1	3	10	Moderate	11	Moderate
Spink	37	5	1	13	5	$762,242	5	4.4	3	14	High	14	High
Stanley	21	3	1	11	4	$316,125	3	2	2	9	Moderate	10	Moderate
Sully	20	2	1	8	3	$213,590	2	1.3	1	6	Moderate	7	Moderate
Todd	36	4	1	11	4	$584,882	4	7.1	5	14	High	14	High
Tripp	30	4	2	15	6	$660,351	5	3.4	3	14	High	16	High
Turner	43	5	4	22	8	$1,047,334	6	13.4	6	21	High	24	High
Union	45	6	1	16	6	$1,866,198	7	32.2	8	22	High	22	High

County	Total Events	Prior Event Rating	Damage Rating	Total events >F1	Prior Event Rating > F1	Building Exposure	Building Exposure Rating (Natural Breaks)	Population Density	Pop Density Rating (Natural Breaks)	Vuln. Rating	Vuln. Category	Vuln. ≥F1	Vuln. ≥F1 Category
Walworth	23	3	1	12	5	$664,408	5	7.4	5	14	High	16	High
Yankton	29	4	2	15	6	$2,630,709	8	42.6	8	22	High	24	High
Ziebach	23	3	1	8	3	$134,376	1	1.4	1	6	Moderate	6	Moderate

Source: Amec Foster Wheeler analysis of NCDC data

Winter Storms

Vulnerability Factors

Prior Events—This rating is based on the number of past winter storms experienced by each county between January 1993 and August 2016 according to data from the National Climatic Data Center's Storm Events database (a compilation of storm data from the National Weather Service). The database does not have information for winter storms prior to 1993. Although the University of South Carolina Hazards and Vulnerability Research Institute's Spatial Hazard Events and Losses Database for the United States (SHELDUS) has events from 1963-2011, it only includes those events for which damage was reported, thus it is not as comprehensive as the National Climatic Data Center. The winter storm profile in Section 3.2.2 describes events that happened before 1993, but that data is not appropriate for this vulnerability assessment. This information was verified during the 2013 update, and the NCDC database remains the most comprehensive dataset for assessing vulnerability.

To develop the prior event rating, the total range of past occurrences (38 to 117) was divided into 10 roughly equal ranges as shown in Table 13. The ranges were numbered 1 through 10 in ascending order.

Table 13 Winter Storm Prior Event Ratings

# of Past Occurrences	Rating
38-45	1
46-53	2
54-61	3
62-69	4
70-77	5
78-85	6
86-93	7
94-101	8

102-109	9
110-117	10

A fourth factor, past winter storm damage, may be considered for the next plan update based on the availability of information. Currently, county-level damage information is not available for winter storms. The damage values captured in the National Climatic Data Center's Storm Event database are for an entire event and cannot be approximated for each individual county.

After rating each of the counties on the factors described above, each factor was separately added with building exposure ratings and population density ratings to produce a county-level vulnerability rating. The highest possible total vulnerability rating is 28. The range of vulnerability (3 to 28) was divided into three equal ranges as shown in Table 14. The ranges were assigned a corresponding level of winter storm vulnerability: moderate, high, and very high.

Table 14 Winter Storm Vulnerability

Winter Storm Vulnerability Range	Winter Storm Vulnerability
3-11	Moderate
12-20	High
21-28	Very High

The table below provides details on each counties' individual ratings for each factor.

Table 15 Winter Storm Vulnerability Calculations

County	Total Events	Prior Event Rating	Total Building Exposure	Building Exposure Rating (Natural	New Population Density	Pop Density Rating (Natural	Vuln. Rating	Vuln. Rating Category
Aurora	84	6	$343,330	3	3.9	3	12	High
Beadle	83	6	$1,950,510	7	14.4	7	20	High
Bennett	54	3	$247,449	2	2.9	3	8	Moderate
Bon Homme	85	6	$684,668	5	12.1	6	17	High

County	Total Events	Prior Event Rating	Total Building Exposure	Building Exposure Rating (Natural	New Population Density	Pop Density Rating (Natural	Vuln. Rating	Vuln. Rating Category
Brookings	92	7	$3,232,047	8	41.4	8	23	Very High
Brown	71	5	$4,022,770	8	22.2	8	21	Very High
Brule	82	6	$598,841	4	6.3	4	14	High
Buffalo	49	2	$114,735	1	4.3	3	6	Moderate
Butte	79	6	$859,242	5	4.5	4	15	High
Campbell	53	2	$211,527	2	1.8	2	6	Moderate
Charles Mix	83	6	$979,078	6	8.1	5	17	High
Clark	62	4	$461,331	4	3.8	3	11	Moderate
Clay	64	4	$1,352,347	6	33.4	8	18	High
Codington	59	3	$3,141,546	8	39.0	8	19	High
Corson	56	3	$261,189	2	1.7	1	6	Moderate
Custer	38	1	$1,059,574	6	5.4	4	11	Moderate
Davison	80	6	$2,033,945	7	45.5	9	22	Very High
Day	72	5	$739,380	5	5.1	4	14	High
Deuel	63	4	$557,548	4	6.8	5	13	High
Dewey	59	3	$326,693	3	2.3	2	8	Moderate
Douglas	70	5	$410,033	3	6.8	5	13	High
Edmunds	76	5	$428,157	4	3.5	3	12	High
Fall River	51	2	$772,078	5	3.9	3	10	Moderate
Faulk	69	4	$319,966	3	2.3	2	9	Moderate
Grant	71	5	$852,422	5	10.5	6	16	High
Gregory	74	5	$499,638	4	4.0	3	12	High
Haakon	53	2	$304,961	3	1.0	1	6	Moderate
Hamlin	58	3	$657,563	5	11.1	6	14	High
Hand	65	4	$489,795	4	2.3	2	10	Moderate
Hanson	83	6	$375,684	3	7.8	5	14	High
Harding	76	5	$134,729	1	0.5	1	7	Moderate
Hughes	57	3	$2,011,351	7	22.0	7	17	High
Hutchinson	88	7	$921,743	6	8.8	5	18	High
Hyde	57	3	$174,088	2	1.6	1	6	Moderate
Jackson	58	3	$279,813	2	1.7	1	6	Moderate
Jerauld	79	6	$292,480	2	3.8	3	11	Moderate
Jones	52	2	$154,067	1	1.0	1	4	Moderate
Kingsbury	79	6	$718,391	5	5.9	4	15	High
Lake	86	7	$1,464,020	7	21.5	7	21	Very High
Lawrence	69	4	$2,942,654	8	30.8	8	20	High
Lincoln	83	6	$4,858,425	9	89.1	9	24	Very High
Lyman	57	3	$387,530	3	2.3	2	8	Moderate

County	Total Events	Prior Event Rating	Total Building Exposure	Building Exposure Rating (Natural	New Population Density	Pop Density Rating (Natural	Vuln. Rating	Vuln. Rating Category
Marshall	78	6	$613,226	4	6.4	5	15	High
McCook	88	7	$337,182	3	4.2	3	13	High
McPherson	66	4	$569,412	4	4.1	3	11	Moderate
Meade	114	10	$2,374,927	7	7.7	5	22	Very High
Mellette	50	2	$145,156	1	1.6	1	4	Moderate
Miner	79	6	$300,577	2	4.0	3	11	Moderate
Minnehaha	96	8	$19,134,385	10	224.8	10	28	Very High
Moody	78	6	$752,929	5	12.2	6	17	High
Oglala Lakota	54	3	$762,242	5	6.8	5	13	High
Pennington	66	4	$349,270	10	38.9	8	22	Very High
Perkins	68	4	$405,402	3	1.0	1	8	Moderate
Potter	62	4	$993,542	3	2.6	2	9	Moderate
Roberts	83	6	$331,251	6	9.1	6	18	High
Sanborn	66	4	$623,369	3	4.1	3	10	Moderate
Spink	71	5	$11,128,870	5	4.4	3	13	High
Stanley	48	2	$316,125	3	2.0	2	7	Moderate
Sully	58	3	$213,590	2	1.3	1	6	Moderate
Todd	50	2	$584,882	4	7.1	5	11	Moderate
Tripp	54	3	$660,351	5	3.4	3	11	Moderate
Turner	86	7	$1,047,334	6	13.4	6	19	High
Union	67	4	$1,866,198	7	32.2	8	19	High
Walworth	59	3	$664,408	5	7.4	5	13	High
Yankton	77	5	$2,630,709	8	42.6	8	21	Very High
Ziebach	54	3	$134,376	1	1.4	1	5	Moderate

Hazus-MH: Earthquake Event Report

Region Name: SouthDakota

Earthquake Scenario: Annualized Loss

Print Date: September 08, 2016

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

Hazus is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 66 county(ies) from the following state(s):

South Dakota

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 77,095.39 square miles and contains 222 census tracts. There are over 322 thousand households in the region which has a total population of 814,180 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 343 thousand buildings in the region with a total building replacement value (excluding contents) of 89,645 (millions of dollars). Approximately 90.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 58,412 and 21,607 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 343 thousand buildings in the region which have an aggregate total replacement value of 89,645 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 75% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 54 hospitals in the region with a total bed capacity of 4,538 beds. There are 832 schools, 278 fire stations, 157 police stations and 24 emergency operation facilities. With respect to high potential loss facilities (HPL), there are 0 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 161 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 80,019.00 (millions of dollars). This inventory includes over 11,937 kilometers of highways, 5,122 bridges, 68,980 kilometers of pipes.

Table 1: Transportation System Lifeline Inventory

System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	5,122	2,373.70
	Segments	1,628	48,254.10
	Tunnels	0	0.00
		Subtotal	**50,627.80**
Railways	Bridges	0	0.00
	Facilities	16	42.60
	Segments	1,103	2,936.00
	Tunnels	0	0.00
		Subtotal	**2,978.60**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	20	19.40
		Subtotal	**19.40**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	68	724.30
	Runways	107	4,062.10
		Subtotal	**4,786.40**
		Total	**58,412.10**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	689.80
	Facilities	7	207.50
	Pipelines	0	0.00
		Subtotal	**897.30**
Waste Water	Distribution Lines	NA	413.90
	Facilities	341	20,212.40
	Pipelines	0	0.00
		Subtotal	**20,626.30**
Natural Gas	Distribution Lines	NA	275.90
	Facilities	1	1.00
	Pipelines	0	0.00
		Subtotal	**276.90**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	12	1,174.80
		Subtotal	**1,174.80**
Communication	Facilities	134	11.90
		Subtotal	**11.90**
		Total	**22,987.20**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	Annualized
Type of Earthquake	Probabilistic
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	Annualized
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	NA
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Hazus estimates that about 4,537 buildings will be at least moderately damaged. This is over 1.00 % of the buildings in the region. There are an estimated 1 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	5,005	1.67	158	1.05	15	0.35	0	0.00	0	0.00
Commercial	8,282	2.76	66	0.44	5	0.12	0	0.00	0	0.00
Education	90	0.03	0	0.00	0	0.00	0	0.00	0	0.00
Government	287	0.10	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	1,200	0.40	0	0.00	0	0.00	0	0.00	0	0.00
Other Residential	35,501	11.83	4,072	27.02	2,157	50.08	64	27.95	0	0.00
Religion	1,126	0.38	4	0.03	1	0.02	0	0.00	0	0.00
Single Family	248,577	82.84	10,768	71.46	2,129	49.43	165	72.05	1	100.00
Total	**300,068**		**15,068**		**4,307**		**229**		**1**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	243,418	81.12	8652	57.42	978	22.71	8	3.49	0	0.00
Steel	5,620	1.87	26	0.17	10	0.23	0	0.00	0	0.00
Concrete	68	0.02	0	0.00	0	0.00	0	0.00	0	0.00
Precast	300	0.10	0	0.00	0	0.00	0	0.00	0	0.00
RM	89	0.03	0	0.00	0	0.00	0	0.00	0	0.00
URM	23,465	7.82	2418	16.05	1,172	27.21	157	68.56	1	100.00
MH	27,108	9.03	3972	26.36	2,147	49.85	64	27.95	0	0.00
Total	**300,068**		**15,068**		**4,307**		**229**		**1**	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 4,538 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,552 hospital beds (78.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 89.00% of the beds will be back in service. By 30 days, 98.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	54	0	0	54
Schools	832	0	0	832
EOCs	24	0	0	24
PoliceStations	157	0	0	157
FireStations	278	0	0	278

Transportation and Utility Lifeline Damage

Table 6 provides damage estimates for the transportation system.

Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	1,628	0	0	1,628	1,628
	Bridges	5,122	0	0	5,122	5,122
	Tunnels	0	0	0	0	0
Railways	Segments	1,103	0	0	1,103	1,103
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	16	0	0	16	16
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	20	0	0	20	20
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	68	0	0	68	68
	Runways	107	0	0	107	107

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	7	0	0	7	7
Waste Water	341	0	0	340	341
Natural Gas	1	0	0	1	1
Oil Systems	0	0	0	0	0
Electrical Power	12	0	0	12	12
Communication	134	0	0	134	134

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	34,490	142	35
Waste Water	20,694	101	25
Natural Gas	13,796	29	7
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	322,282	0	0	0	0	0
Electric Power		0	0	0	0	0

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.18 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 67.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 7,160 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 336 households to be displaced due to the earthquake. Of these, 204 people (out of a total population of 814,180) will seek temporary shelter in public shelters.

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	0	0	0	0
	Single Family	0	0	0	0
	Total	**0**	**0**	**0**	**0**
2 PM	Commercial	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	0	0	0	0
	Single Family	0	0	0	0
	Total	**0**	**0**	**0**	**0**
5 PM	Commercial	0	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	0	0	0	0
	Other-Residential	0	0	0	0
	Single Family	0	0	0	0
	Total	**0**	**0**	**0**	**0**

Economic Loss

The total economic loss estimated for the earthquake is 371.25 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 0.60 (millions of dollars); 29 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 53 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.00	0.00	0.03	0.00	0.00	0.04
	Capital-Related	0.00	0.00	0.03	0.00	0.00	0.03
	Rental	0.01	0.01	0.02	0.00	0.00	0.03
	Relocation	0.02	0.01	0.02	0.00	0.01	0.07
	Subtotal	**0.03**	**0.03**	**0.10**	**0.00**	**0.01**	**0.18**
Capital Stock Losses							
	Structural	0.04	0.02	0.03	0.00	0.01	0.10
	Non_Structural	0.12	0.05	0.05	0.01	0.02	0.24
	Content	0.03	0.01	0.02	0.01	0.01	0.08
	Inventory	0.00	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.19**	**0.08**	**0.10**	**0.02**	**0.04**	**0.43**
	Total	**0.22**	**0.10**	**0.21**	**0.02**	**0.05**	**0.60**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Hazus estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 14 presents the results of the region for the given earthquake.

Table 12: Transportation System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	48,254.10	$0.00	0.00
	Bridges	2,373.66	$0.38	0.02
	Tunnels	0.00	$0.00	0.00
	Subtotal	**50627.80**	**0.40**	
Railways	Segments	2,935.95	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	42.61	$1.90	4.45
	Subtotal	**2978.60**	**1.90**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	19.40	$0.95	4.88
	Subtotal	**19.40**	**0.90**	
Ferry	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Port	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Airport	Facilities	724.27	$39.09	5.40
	Runways	4,062.15	$0.00	0.00
	Subtotal	**4786.40**	**39.10**	
	Total	**58412.10**	**42.30**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	207.50	$2.16	1.04
	Distribution Lines	689.80	$0.64	0.09
	Subtotal	**897.26**	**$2.80**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	20,212.40	$308.52	1.53
	Distribution Lines	413.90	$0.46	0.11
	Subtotal	**20,626.31**	**$308.98**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.00	$0.00	0.47
	Distribution Lines	275.90	$0.13	0.05
	Subtotal	**276.89**	**$0.14**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	1,174.80	$16.24	1.38
	Subtotal	**1,174.80**	**$16.24**	
Communication	Facilities	11.90	$0.19	1.56
	Subtotal	**11.93**	**$0.19**	
	Total	**22,987.19**	**$328.33**	

Table 14. Indirect Economic Impact with outside aid

(Employment as # of people and Income in millions of $)

LOSS		Total	%

Appendix A: County Listing for the Region

Aurora,SD

Beadle,SD

Bennett,SD

Bon Homme,SD

Brookings,SD

Brown,SD

Brule,SD

Buffalo,SD

Butte,SD

Campbell,SD

Charles Mix,SD

Clark,SD

Clay,SD

Codington,SD

Corson,SD

Custer,SD

Davison,SD

Day,SD

Deuel,SD

Dewey,SD

Douglas,SD

Edmunds,SD

Fall River,SD

Faulk,SD

Grant,SD

Gregory,SD

Haakon,SD

Hamlin,SD

Hand,SD

Hanson,SD

Harding,SD

Hughes,SD

Hutchinson,SD

Hyde,SD

Jackson,SD

Jerauld,SD

Jones,SD

Kingsbury,SD

Lake,SD

Lawrence,SD

Lincoln,SD

Lyman,SD

McCook,SD

McPherson,SD

Marshall,SD

Meade,SD

Mellette,SD

Miner,SD

Minnehaha,SD

Moody,SD

Pennington,SD

Perkins,SD

Potter,SD

Roberts,SD

Sanborn,SD

Shannon,SD

Spink,SD

Stanley,SD

Sully,SD

Todd,SD

Tripp,SD

Turner,SD

Union,SD

Walworth,SD

Yankton,SD

Ziebach,SD

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
South Dakota					
	Aurora	2,710	270	72	343
	Beadle	17,398	1,448	502	1,950
	Bennett	3,431	201	46	247
	Bon Homme	7,070	510	173	684
	Brookings	31,965	2,548	683	3,232
	Brown	36,531	3,021	1,001	4,022
	Brule	5,255	440	157	598
	Buffalo	1,912	87	27	114
	Butte	10,110	703	155	859
	Campbell	1,466	169	42	211
	Charles Mix	9,129	692	286	979
	Clark	3,691	358	102	461
	Clay	13,864	1,087	264	1,352
	Codington	27,227	2,296	845	3,141
	Corson	4,050	212	49	261
	Custer	8,216	921	138	1,059
	Davison	19,504	1,560	473	2,033
	Day	5,710	585	153	739
	Deuel	4,364	458	99	557
	Dewey	5,301	273	53	326
	Douglas	3,002	308	101	410
	Edmunds	4,071	401	105	506
	Fall River	7,094	611	160	772
	Faulk	2,364	243	76	319
	Grant	7,356	645	207	852
	Gregory	4,271	369	130	499
	Haakon	1,937	218	86	304
	Hamlin	5,903	512	144	657
	Hand	3,431	361	128	489
	Hanson	3,331	314	61	375
	Harding	1,255	102	32	134
	Hughes	17,022	1,436	574	2,011
	Hutchinson	7,343	681	240	921
	Hyde	1,420	123	50	174
	Jackson	3,031	234	45	279
	Jerauld	2,071	216	76	292
	Jones	1,006	117	36	154
	Kingsbury	5,148	563	155	718
	Lake	11,200	1,146	317	1,464
	Lawrence	24,097	2,355	586	2,942
	Lincoln	44,828	4,270	587	4,858
	Lyman	3,755	287	100	387
	McCook	5,618	475	137	613
	McPherson	2,459	239	97	337

	Marshall	4,656	447	121	569
	Meade	25,434	1,946	428	2,374
	Mellette	2,048	116	28	145
	Miner	2,389	228	72	300
	Minnehaha	169,468	14,444	4,690	19,134
	Moody	6,486	619	133	752
	Pennington	100,948	8,463	2,665	11,128
	Perkins	2,982	245	103	349
	Potter	2,329	241	164	405
	Roberts	10,149	783	209	993
	Sanborn	2,355	265	65	331
	Shannon	13,586	447	176	623
	Spink	6,415	578	183	762
	Stanley	2,966	250	65	316
	Sully	1,373	164	49	213
	Todd	9,612	472	112	584
	Tripp	5,644	461	199	660
	Turner	8,347	787	259	1,047
	Union	14,399	1,333	532	1,866
	Walworth	5,438	495	169	664
	Yankton	22,438	1,881	748	2,630
	Ziebach	2,801	119	14	134
Total State		**814,180**	**68,849**	**20,734**	**89,614**
Total Region		**814,180**	**68,849**	**20,734**	**89,614**

Direct Economic Losses For Buildings

September 13, 2016

All values are in thousands of dollars

	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
South Dakota										
Dewey	0	0	0	0	0.00	0	0	0	0	1
Beadle	3	7	3	0	0.00	2	1	1	1	18
Corson	0	0	0	0	0.00	0	0	0	0	0
Harding	0	0	0	0	0.00	0	0	0	0	0
Deuel	0	0	0	0	0.00	0	0	0	0	1
Lake	1	2	1	0	0.00	1	0	0	0	6
Sanborn	1	1	1	0	0.00	0	0	0	0	3
Hanson	0	1	0	0	0.00	0	0	0	0	3
Ziebach	0	0	0	0	0.00	0	0	0	0	0
Perkins	0	0	0	0	0.00	0	0	0	0	1
Codington	2	4	1	0	0.00	1	1	1	1	10
Turner	1	2	1	0	0.00	1	0	0	0	5
Brule	1	4	1	0	0.00	1	0	1	0	9

Study Region : SouthDakota

Scenario : 2,500yr 5.5mag

Earthquake Hazard Report

	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Hand	1	2	1	0	0.00	0	0	0	0	4
Hutchinson	1	3	1	0	0.00	1	0	0	0	7
Pennington	24	58	19	0	0.00	16	10	12	9	148
Bon Homme	1	2	1	0	0.00	1	0	0	0	6
McCook	1	1	0	0	0.00	0	0	0	0	3
Douglas	1	2	1	0	0.00	0	0	0	0	5
Bennett	1	2	1	0	0.00	0	0	0	0	5
Walworth	0	1	0	0	0.00	0	0	0	0	1
Campbell	0	0	0	0	0.00	0	0	0	0	0
Day	0	1	0	0	0.00	0	0	0	0	2
Jackson	0	1	0	0	0.00	0	0	0	0	3
Kingsbury	1	1	0	0	0.00	0	0	0	0	3
Roberts	0	1	0	0	0.00	0	0	0	0	2
Butte	1	3	1	0	0.00	1	0	0	0	7
Miner	0	1	0	0	0.00	0	0	0	0	2
Grant	0	1	0	0	0.00	0	0	0	0	2
Jerauld	1	2	1	0	0.00	0	0	0	0	4
Clay	1	3	1	0	0.00	1	0	0	0	6

Study Region : SouthDakota

Scenario : 2,500yr 5.5mag

	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Potter	0	1	0	0	0.00	0	0	0	0	2
Yankton	3	7	2	0	0.00	2	1	1	1	17
Tripp	1	3	1	0	0.00	1	0	1	0	8
Buffalo	0	1	0	0	0.00	0	0	0	0	1
Oglala Lakota	2	6	2	0	0.00	2	0	0	0	13
Meade	4	9	3	0	0.00	2	1	1	1	21
Fall River	3	9	4	0	0.00	2	1	1	1	22
Lincoln	3	6	2	0	0.00	1	0	1	1	14
Lawrence	5	13	4	0	0.00	4	2	3	2	34
Edmunds	0	0	0	0	0.00	0	0	0	0	1
Davison	3	8	3	0	0.00	2	1	1	1	20
Minnehaha	13	28	8	0	0.00	8	4	5	5	71
Marshall	0	0	0	0	0.00	0	0	0	0	1
Gregory	1	3	1	0	0.00	1	0	0	0	7
Hughes	2	5	2	0	0.00	1	1	1	1	12
Spink	1	1	0	0	0.00	0	0	0	0	3
Brookings	2	4	1	0	0.00	1	1	1	1	10
Clark	0	1	0	0	0.00	0	0	0	0	2

Study Region : SouthDakota

Scenario : 2,500yr 5.5mag

	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Todd	1	3	1	0	0.00	1	0	0	0	6
Mellette	0	1	0	0	0.00	0	0	0	0	1
Faulk	0	1	0	0	0.00	0	0	0	0	1
Custer	3	8	3	0	0.00	2	1	1	1	19
Aurora	1	2	1	0	0.00	0	0	0	0	5
Lyman	1	1	1	0	0.00	0	0	0	0	4
McPherson	0	0	0	0	0.00	0	0	0	0	1
Brown	2	4	1	0	0.00	1	1	1	1	11
Haakon	0	1	0	0	0.00	0	0	0	0	2
Jones	0	0	0	0	0.00	0	0	0	0	1
Moody	0	1	0	0	0.00	0	0	0	0	2
Sully	0	0	0	0	0.00	0	0	0	0	1
Stanley	0	1	0	0	0.00	0	0	0	0	2
Hamlin	0	1	0	0	0.00	0	0	0	0	2
Hyde	0	0	0	0	0.00	0	0	0	0	1
Union	1	3	1	0	0.00	1	0	0	0	6
Charles Mix	2	6	2	0	0.00	1	2	2	1	16

Study Region : SouthDakota

Scenario : 2,500yr 5.5mag

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	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Total	101	243	82	2	0.00	66	33	43	34	604
Region Total	101	243	82	2	0.00	66	33	43	34	604

Totals only reflect data for those census tracts/blocks included in the user's study region and will reflect the entire county/state only if all of the census blocks for that county/states were selected at the time of study region creation.

Hazus-MH: Earthquake Event Report

Region Name: SouthDakota

Earthquake Scenario: 2,500yr 5.5mag

Print Date: September 08, 2016

Disclaimer:
This version of Hazus utilizes 2010 Census Data.
Totals only reflect data for those census tracts/blocks included in the user's study region.

The estimates of social and economic impacts contained in this report were produced using Hazus loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

Hazus is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of Hazus is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 66 county(ies) from the following state(s):

South Dakota

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 77,095.39 square miles and contains 222 census tracts. There are over 322 thousand households in the region which has a total population of 814,180 people (2010 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 343 thousand buildings in the region with a total building replacement value (excluding contents) of 89,645 (millions of dollars). Approximately 90.00 % of the buildings (and 77.00% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 58,412 and 21,607 (millions of dollars) , respectively.

Building and Lifeline Inventory

Building Inventory

Hazus estimates that there are 343 thousand buildings in the region which have an aggregate total replacement value of 89,645 (millions of dollars) . Appendix B provides a general distribution of the building value by State and County.

In terms of building construction types found in the region, wood frame construction makes up 75% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

Hazus breaks critical facilities into two (2) groups: essential facilities and high potential loss facilities (HPL). Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 54 hospitals in the region with a total bed capacity of 4,538 beds. There are 832 schools, 278 fire stations, 157 police stations and 24 emergency operation facilities. With respect to high potential loss facilities (HPL), there are 0 dams identified within the region. Of these, 0 of the dams are classified as 'high hazard'. The inventory also includes 161 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within Hazus, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data are provided in Tables 1 and 2.

The total value of the lifeline inventory is over 80,019.00 (millions of dollars). This inventory includes over 11,937 kilometers of highways, 5,122 bridges, 68,980 kilometers of pipes.

Table 1: Transportation System Lifeline Inventory

System	Component	# Locations/ # Segments	Replacement value (millions of dollars)
Highway	Bridges	5,122	2,373.70
	Segments	1,628	48,254.10
	Tunnels	0	0.00
		Subtotal	**50,627.80**
Railways	Bridges	0	0.00
	Facilities	16	42.60
	Segments	1,103	2,936.00
	Tunnels	0	0.00
		Subtotal	**2,978.60**
Light Rail	Bridges	0	0.00
	Facilities	0	0.00
	Segments	0	0.00
	Tunnels	0	0.00
		Subtotal	**0.00**
Bus	Facilities	20	19.40
		Subtotal	**19.40**
Ferry	Facilities	0	0.00
		Subtotal	**0.00**
Port	Facilities	0	0.00
		Subtotal	**0.00**
Airport	Facilities	68	724.30
	Runways	107	4,062.10
		Subtotal	**4,786.40**
		Total	**58,412.10**

Table 2: Utility System Lifeline Inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Distribution Lines	NA	689.80
	Facilities	7	207.50
	Pipelines	0	0.00
		Subtotal	**897.30**
Waste Water	Distribution Lines	NA	413.90
	Facilities	341	20,212.40
	Pipelines	0	0.00
		Subtotal	**20,626.30**
Natural Gas	Distribution Lines	NA	275.90
	Facilities	1	1.00
	Pipelines	0	0.00
		Subtotal	**276.90**
Oil Systems	Facilities	0	0.00
	Pipelines	0	0.00
		Subtotal	**0.00**
Electrical Power	Facilities	12	1,174.80
		Subtotal	**1,174.80**
Communication	Facilities	134	11.90
		Subtotal	**11.90**
		Total	**22,987.20**

Earthquake Scenario

Hazus uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	2,500yr 5.5mag
Type of Earthquake	Probabilistic
Fault Name	NA
Historical Epicenter ID #	NA
Probabilistic Return Period	2,500.00
Longitude of Epicenter	NA
Latitude of Epicenter	NA
Earthquake Magnitude	5.50
Depth (Km)	NA
Rupture Length (Km)	NA
Rupture Orientation (degrees)	NA
Attenuation Function	NA

Building Damage

Hazus estimates that about 6,930 buildings will be at least moderately damaged. This is over 2.00 % of the buildings in the region. There are an estimated 62 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 below summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	6,193	1.95	482	2.61	170	2.77	28	3.83	2	2.91
Commercial	16,980	5.33	1,520	8.23	710	11.58	130	17.73	9	14.29
Education	755	0.24	58	0.32	26	0.42	3	0.47	0	0.69
Government	1,076	0.34	76	0.41	34	0.55	4	0.55	1	0.82
Industrial	4,250	1.34	368	2.00	186	3.04	34	4.60	2	2.75
Other Residential	38,482	12.09	4,830	26.16	2,584	42.11	183	24.94	9	14.22
Religion	1,816	0.57	147	0.80	66	1.08	13	1.75	1	2.17
Single Family	248,792	78.15	10,981	59.48	2,360	38.46	338	46.13	39	62.14
Total	**318,344**		**18,461**		**6,136**		**732**		**63**	

Table 4: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	246,131	77.32	9323	50.50	1,169	19.06	64	8.80	0	0.05
Steel	13,764	4.32	1106	5.99	590	9.62	98	13.33	2	3.35
Concrete	1,470	0.46	101	0.54	37	0.61	3	0.46	0	0.10
Precast	1,784	0.56	121	0.65	92	1.50	21	2.94	0	0.40
RM	859	0.27	49	0.26	32	0.52	6	0.76	0	0.02
URM	27,028	8.49	3594	19.47	1,877	30.60	401	54.80	56	89.10
MH	27,309	8.58	4169	22.58	2,337	38.10	138	18.91	4	6.97
Total	**318,344**		**18,461**		**6,136**		**732**		**63**	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Essential Facility Damage

Before the earthquake, the region had 4,538 hospital beds available for use. On the day of the earthquake, the model estimates that only 3,552 hospital beds (78.00%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 89.00% of the beds will be back in service. By 30 days, 98.00% will be operational.

Table 5: Expected Damage to Essential Facilities

Classification	Total	# Facilities		
		At Least Moderate Damage > 50%	Complete Damage > 50%	With Functionality > 50% on day 1
Hospitals	54	0	0	54
Schools	832	0	0	832
EOCs	24	0	0	24
PoliceStations	157	0	0	157
FireStations	278	0	0	278

Transportation and Utility Lifeline Damage

Table 6 provides damage estimates for the transportation system.

Table 6: Expected Damage to the Transportation Systems

System	Component		Number of Locations			
		Locations/ Segments	With at Least Mod. Damage	With Complete Damage	With Functionality > 50 %	
					After Day 1	After Day 7
Highway	Segments	1,628	0	0	1,628	1,628
	Bridges	5,122	0	0	5,122	5,122
	Tunnels	0	0	0	0	0
Railways	Segments	1,103	0	0	1,103	1,103
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	16	0	0	16	16
Light Rail	Segments	0	0	0	0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	Facilities	20	0	0	20	20
Ferry	Facilities	0	0	0	0	0
Port	Facilities	0	0	0	0	0
Airport	Facilities	68	0	0	68	68
	Runways	107	0	0	107	107

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 7-9 provide information on the damage to the utility lifeline systems. Table 7 provides damage to the utility system facilities. Table 8 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, Hazus performs a simplified system performance analysis. Table 9 provides a summary of the system performance information.

Table 7 : Expected Utility System Facility Damage

System	# of Locations				
	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 %	
				After Day 1	After Day 7
Potable Water	7	0	0	7	7
Waste Water	341	0	0	340	341
Natural Gas	1	0	0	1	1
Oil Systems	0	0	0	0	0
Electrical Power	12	0	0	12	12
Communication	134	0	0	134	134

Table 8 : Expected Utility System Pipeline Damage (Site Specific)

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	34,490	142	35
Waste Water	20,694	101	25
Natural Gas	13,796	29	7
Oil	0	0	0

Table 9: Expected Potable Water and Electric Power System Performance

	Total # of Households	Number of Households without Service				
		At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	322,282	0	0	0	0	0
Electric Power		0	0	0	0	0

Debris Generation

Hazus estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.18 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 67.00% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 7,160 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

Hazus estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 336 households to be displaced due to the earthquake. Of these, 204 people (out of a total population of 814,180) will seek temporary shelter in public shelters.

Casualties

Hazus estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

- Severity Level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity Level 2: Injuries will require hospitalization but are not considered life-threatening
- Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum and 5:00 PM represents peak commute time.

Table 10 provides a summary of the casualties estimated for this earthquake

Table 10: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Commercial	1	0	0	0
	Commuting	0	0	0	0
	Educational	0	0	0	0
	Hotels	0	0	0	0
	Industrial	2	0	0	0
	Other-Residential	50	7	0	1
	Single Family	49	6	1	1
	Total	**102**	**13**	**1**	**2**
2 PM	Commercial	84	12	1	2
	Commuting	0	0	0	0
	Educational	30	5	0	1
	Hotels	0	0	0	0
	Industrial	13	2	0	0
	Other-Residential	10	1	0	0
	Single Family	9	1	0	0
	Total	**146**	**21**	**2**	**3**
5 PM	Commercial	61	9	1	1
	Commuting	0	0	0	0
	Educational	3	0	0	0
	Hotels	0	0	0	0
	Industrial	8	1	0	0
	Other-Residential	19	3	0	0
	Single Family	19	3	0	0
	Total	**110**	**15**	**1**	**3**

Economic Loss

The total economic loss estimated for the earthquake is 949.15 (millions of dollars), which includes building and lifeline related losses based on the region's available inventory. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 578.51 (millions of dollars); 25 % of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 55 % of the total loss. Table 11 below provides a summary of the losses associated with the building damage.

Table 11: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Single Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses							
	Wage	0.00	4.02	27.54	0.73	2.57	34.86
	Capital-Related	0.00	1.72	23.48	0.44	0.50	26.13
	Rental	5.25	9.46	12.17	0.29	0.82	27.99
	Relocation	17.68	7.66	19.66	1.71	7.31	54.02
	Subtotal	**22.94**	**22.85**	**82.85**	**3.18**	**11.20**	**143.00**
Capital Stock Losses							
	Structural	33.06	14.16	22.67	3.83	9.37	83.10
	Non_Structural	126.04	46.61	48.99	9.83	19.05	250.51
	Content	43.27	10.95	26.94	6.35	11.64	99.15
	Inventory	0.00	0.00	0.81	1.39	0.55	2.75
	Subtotal	**202.37**	**71.73**	**99.40**	**21.40**	**40.61**	**435.51**
	Total	**225.31**	**94.57**	**182.25**	**24.58**	**51.80**	**578.51**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, Hazus computes the direct repair cost for each component only. There are no losses computed by Hazus for business interruption due to lifeline outages. Tables 12 & 13 provide a detailed breakdown in the expected lifeline losses.

Hazus estimates the long-term economic impacts to the region for 15 years after the earthquake. The model quantifies this information in terms of income and employment changes within the region. Table 14 presents the results of the region for the given earthquake.

Table 12: Transportation System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Segments	48,254.10	$0.00	0.00
	Bridges	2,373.66	$0.38	0.02
	Tunnels	0.00	$0.00	0.00
	Subtotal	**50627.80**	**0.40**	
Railways	Segments	2,935.95	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	42.61	$1.90	4.45
	Subtotal	**2978.60**	**1.90**	
Light Rail	Segments	0.00	$0.00	0.00
	Bridges	0.00	$0.00	0.00
	Tunnels	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Bus	Facilities	19.40	$0.95	4.88
	Subtotal	**19.40**	**0.90**	
Ferry	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Port	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**0.00**	
Airport	Facilities	724.27	$39.09	5.40
	Runways	4,062.15	$0.00	0.00
	Subtotal	**4786.40**	**39.10**	
	Total	**58412.10**	**42.30**	

Table 13: Utility System Economic Losses

(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.00	$0.00	0.00
	Facilities	207.50	$2.16	1.04
	Distribution Lines	689.80	$0.64	0.09
	Subtotal	**897.26**	**$2.80**	
Waste Water	Pipelines	0.00	$0.00	0.00
	Facilities	20,212.40	$308.52	1.53
	Distribution Lines	413.90	$0.46	0.11
	Subtotal	**20,626.31**	**$308.98**	
Natural Gas	Pipelines	0.00	$0.00	0.00
	Facilities	1.00	$0.00	0.47
	Distribution Lines	275.90	$0.13	0.05
	Subtotal	**276.89**	**$0.14**	
Oil Systems	Pipelines	0.00	$0.00	0.00
	Facilities	0.00	$0.00	0.00
	Subtotal	**0.00**	**$0.00**	
Electrical Power	Facilities	1,174.80	$16.24	1.38
	Subtotal	**1,174.80**	**$16.24**	
Communication	Facilities	11.90	$0.19	1.56
	Subtotal	**11.93**	**$0.19**	
	Total	**22,987.19**	**$328.33**	

Table 14. Indirect Economic Impact with outside aid

(Employment as # of people and Income in millions of $)

LOSS	Total	%

Appendix A: County Listing for the Region

Aurora,SD

Beadle,SD

Bennett,SD

Bon Homme,SD

Brookings,SD

Brown,SD

Brule,SD

Buffalo,SD

Butte,SD

Campbell,SD

Charles Mix,SD

Clark,SD

Clay,SD

Codington,SD

Corson,SD

Custer,SD

Davison,SD

Day,SD

Deuel,SD

Dewey,SD

Douglas,SD

Edmunds,SD

Fall River,SD

Faulk,SD

Grant,SD

Gregory,SD

Haakon,SD

Hamlin,SD

Hand,SD

Hanson,SD

Harding,SD

Hughes,SD

Hutchinson,SD

Hyde,SD

Jackson,SD

Jerauld,SD

Jones,SD

Kingsbury,SD

Lake,SD

Lawrence,SD

Lincoln,SD

Lyman,SD

McCook,SD

McPherson,SD

Marshall,SD

Meade,SD

Mellette,SD

Miner,SD

Minnehaha,SD

Moody,SD

Pennington,SD

Perkins,SD

Potter,SD

Roberts,SD

Sanborn,SD

Shannon,SD

Spink,SD

Stanley,SD

Sully,SD

Todd,SD

Tripp,SD

Turner,SD

Union,SD

Walworth,SD

Yankton,SD

Ziebach,SD

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
South Dakota					
	Aurora	2,710	270	72	343
	Beadle	17,398	1,448	502	1,950
	Bennett	3,431	201	46	247
	Bon Homme	7,070	510	173	684
	Brookings	31,965	2,548	683	3,232
	Brown	36,531	3,021	1,001	4,022
	Brule	5,255	440	157	598
	Buffalo	1,912	87	27	114
	Butte	10,110	703	155	859
	Campbell	1,466	169	42	211
	Charles Mix	9,129	692	286	979
	Clark	3,691	358	102	461
	Clay	13,864	1,087	264	1,352
	Codington	27,227	2,296	845	3,141
	Corson	4,050	212	49	261
	Custer	8,216	921	138	1,059
	Davison	19,504	1,560	473	2,033
	Day	5,710	585	153	739
	Deuel	4,364	458	99	557
	Dewey	5,301	273	53	326
	Douglas	3,002	308	101	410
	Edmunds	4,071	401	105	506
	Fall River	7,094	611	160	772
	Faulk	2,364	243	76	319
	Grant	7,356	645	207	852
	Gregory	4,271	369	130	499
	Haakon	1,937	218	86	304
	Hamlin	5,903	512	144	657
	Hand	3,431	361	128	489
	Hanson	3,331	314	61	375
	Harding	1,255	102	32	134
	Hughes	17,022	1,436	574	2,011
	Hutchinson	7,343	681	240	921
	Hyde	1,420	123	50	174
	Jackson	3,031	234	45	279
	Jerauld	2,071	216	76	292
	Jones	1,006	117	36	154
	Kingsbury	5,148	563	155	718
	Lake	11,200	1,146	317	1,464
	Lawrence	24,097	2,355	586	2,942
	Lincoln	44,828	4,270	587	4,858
	Lyman	3,755	287	100	387
	McCook	5,618	475	137	613
	McPherson	2,459	239	97	337

	Marshall	4,656	447	121	569
	Meade	25,434	1,946	428	2,374
	Mellette	2,048	116	28	145
	Miner	2,389	228	72	300
	Minnehaha	169,468	14,444	4,690	19,134
	Moody	6,486	619	133	752
	Pennington	100,948	8,463	2,665	11,128
	Perkins	2,982	245	103	349
	Potter	2,329	241	164	405
	Roberts	10,149	783	209	993
	Sanborn	2,355	265	65	331
	Shannon	13,586	447	176	623
	Spink	6,415	578	183	762
	Stanley	2,966	250	65	316
	Sully	1,373	164	49	213
	Todd	9,612	472	112	584
	Tripp	5,644	461	199	660
	Turner	8,347	787	259	1,047
	Union	14,399	1,333	532	1,866
	Walworth	5,438	495	169	664
	Yankton	22,438	1,881	748	2,630
	Ziebach	2,801	119	14	134
Total State		**814,180**	**68,849**	**20,734**	**89,614**
Total Region		**814,180**	**68,849**	**20,734**	**89,614**

Appendix 3H. Critical Facilities in Flood and Wildfire Zones

Table 3Ha – Critical Facilities in the DFIRM 1% Annual Chance Floodplain

State Facilities	Count
Army National Guard	3
Board of Regents	12
Depart of Environment & NatRes	1
Department of Agriculture	2
Department of Health	1
Department of Human Services	2
Department of Labor	1
Department of Public Safety	1
Department of Revenue	1
Department of Social Services	1
Department of Transportation	1
Office of the Attorney General	1
State Fuel Sites	2
Total	**29**

Non State Facilities	Count
Airport	1
Communication	14
EMS	4
Fire	12
Natural Gas Facility	6
Police	3
Power	5
Private School	2
Public School	17
Tier II Facilities	60
Waste Water Facility	46
Water Facility	1
Total	**171**

Table 3Hb – Critical Facilities in the DFIRM 0.2% Annual Chance Floodplain

State Facilities	Count
Board of Eng & Arch Examiners	1
Board of Regents	9
Bureau of Info & Telecomm	2
Depart of Environment & NatRes	1
Department of Corrections	3
Department of Labor	1
Department of Public Safety	1
Department of Revenue	1
Department of Social Services	1
Department of Transportation	2
State Fuel Sites	1
Total	**23**

Non State Facilities	Count
Communication	4
EMS	3
Fire	8
Hospital	2
Natural Gas Facility	4
Police	4
Power	3
Public School	10
Substation	2
Tier II Facilities	34
Waste Water Facility	7
Total	**81**

Table 3Hc – Critical Facilities in Areas Protected by Levees

State Facilities	Count
Army National Guard	1
Depart of Military & Vet Affairs	1
Depart of Tourism & State Devel	1
Department of Health	1
Total	**4**

Non State Facilities	Count
Airport	1
Communication	2
EMS	2
Fire	4
Higher Education	1
Natural Gas Facility	1
Private School	4
Public School	7
Tier II Facilities	43
Total	**65**

Table 3Hd – Critical Facilities in the HAZUS 1% Annual Chance Floodplain

Non State Facilities	Count
Airport	1
Communication	4
Fire	4
Hospital	1
Natural Gas Facility	3
Police	2
Public School	13
Tier II Facilities	17
Waste Water Facility	29
Water Facility	1
Total	**75**

*No State Facilities Found

Table 3He – DFIRM and HAZUS Total Flooded Critical Facilities

State vs Non State	Flood	Type	Count
State	0.2% Chance	Board of Eng & Arch Examiners	1
State	0.2% Chance	Board of Regents	9
State	0.2% Chance	Bureau of Info & Telecomm	2
State	0.2% Chance	Depart of Environment & NatRes	1
State	0.2% Chance	Department of Corrections	3
State	0.2% Chance	Department of Labor	1
State	0.2% Chance	Department of Public Safety	1
State	0.2% Chance	Department of Revenue	1
State	0.2% Chance	Department of Social Services	1
State	0.2% Chance	Department of Transportation	2
State	0.2% Chance	State Fuel Sites	1
State	1% Chance	Army National Guard	3
State	1% Chance	Board of Regents	12
State	1% Chance	Depart of Environment & NatRes	1
State	1% Chance	Department of Agriculture	2
State	1% Chance	Department of Health	1
State	1% Chance	Department of Human Services	2
State	1% Chance	Department of Labor	1
State	1% Chance	Department of Public Safety	1
State	1% Chance	Department of Revenue	1
State	1% Chance	Department of Social Services	1
State	1% Chance	Department of Transportation	1
State	1% Chance	Office of the Attorney General	1
State	1% Chance	State Fuel Sites	2
State	Leveed Area	Army National Guard	1
State	Leveed Area	Depart of Military & Vet Affairs	1
State	Leveed Area	Depart of Tourism & State Devel	1
State	Leveed Area	Department of Health	1
Non-State	0.2% Chance	Communication	4
Non-State	0.2% Chance	EMS	3
Non-State	0.2% Chance	Fire	8
Non-State	0.2% Chance	Hospital	2
Non-State	0.2% Chance	Natural Gas Facility	4
Non-State	0.2% Chance	Police	4
Non-State	0.2% Chance	Power	3
Non-State	0.2% Chance	Public School	10
Non-State	0.2% Chance	Substation	2
Non-State	0.2% Chance	Waste Water Facility	7

State vs Non State	Flood	Type	Count
Non-State	1% Chance	Airport	1
Non-State	1% Chance	Communication	14
Non-State	1% Chance	EMS	4
Non-State	1% Chance	Fire	12
Non-State	1% Chance	Natural Gas Facility	6
Non-State	1% Chance	Police	3
Non-State	1% Chance	Power	5
Non-State	1% Chance	Private School	2
Non-State	1% Chance	Public School	17
Non-State	1% Chance	Waste Water Facility	46
Non-State	1% Chance	Water Facility	1
Non-State	Hazus 100yr	Airport	1
Non-State	Hazus 100yr	Communication	4
Non-State	Hazus 100yr	Fire	4
Non-State	Hazus 100yr	Hospital	1
Non-State	Hazus 100yr	Natural Gas Facility	3
Non-State	Hazus 100yr	Police	2
Non-State	Hazus 100yr	Public School	13
Non-State	Hazus 100yr	Waste Water Facility	29
Non-State	Hazus 100yr	Water Facility	1
Non-State	Leveed Area	Airport	1
Non-State	Leveed Area	Communication	2
Non-State	Leveed Area	EMS	2
Non-State	Leveed Area	Fire	4
Non-State	Leveed Area	Higher Education	1
Non-State	Leveed Area	Natural Gas Facility	1
Non-State	Leveed Area	Private School	4
Non-State	Leveed Area	Public School	7

Table 3Hf – Critical Facilities in the High & Moderate Fire Risk Zones

Critical Facilities	Count
Airport	2
Army National Guard	3
Board of Regents	3
Bureau of Administration	3
Bureau of Info & Telecomm	2
Communication	16
Department of Environment & Natural Resources	1
Depart of Game, Fish & Parks	3
Depart of Tourism & State Development	2
Department of Agriculture	1
Department of Corrections	4
Department of Education	2
Department of Health	5
Department of Labor	6
Department of Legislative Audit	1
Department of Public Safety	5
Department of Revenue	3
Department of Social Services	12
Department of Transportation	10
Division of Criminal Investigation	1
EMS	60
Fire	89
HAZMAT	16
Higher Education	1
Hospital	12
Natural Gas Facility	15
Office of the Attorney General	2
Police	40
Power	3
Private School	11
Public School	93
Public Utility Commission	1
SD Building Authority	1
SD Retirement	1
State Fuel Sites	15
Substation	10
Waste Water Facility	26
Total	**481**

Table 3Hg-State Facilities in Fire Zones by State Agency

Agency	Count
BOA	7
DDN	34
DOA	1
DOC	3
DOH	10
DPS	5
DRR	2
DSS	14
Educational Facility	6
Electric Power	1
GFP	11
Natural Gas Pipe	1
Office Building	1
TSD	3
Unknown	1
Total	**100**

Table 3Hh- State Facilities within a 0.5 mile buffer of Tier II Facilities by County

County	Count
Aurora	2
Beadle	15
Bon Homme	3
Brookings	37
Brown	34
Brule	5
Butte	5
Campbell	2
Charles Mix	6
Clark	1
Clay	29
Codington	7
Corson	3
Custer	6
Davison	8
Day	2
Deuel	2
Dewey	6
Douglas	2
Edmunds	2
Fall River	7

County	Count
Faulk	2
Grant	2
Gregory	2
Haakon	2
Hand	2
Harding	1
Hughes	67
Hutchinson	2
Hyde	2
Jackson	1
Jerauld	1
Kingsbury	2
Lake	10
Lawrence	26
Lincoln	5
Lyman	2
Marshall	1
McCook	2
McPherson	2
Meade	4
Minnehaha	24
Moody	1
Oglala Lakota	2
Pennington	55
Perkins	6
Potter	1
Roberts	6
Sanborn	2
Stanley	1
Todd	3
Tripp	4
Union	1
Walworth	2
Yankton	8
Ziebach	2
Total	**440**

Table 3Hi- State Facilities within a 0.5 mile buffer of Tier II Facilities

State Facilities	Count
Airport	1
Army National Guard	21
Board of Eng & Arch Examiners	1
Board of Regents	137
Bureau of Administration	9
Bureau of Info & Telecomm	7
Bureau of Personnel	1
Depart of Environment & NatRes	4
Depart of Game, Fish & Parks	6
Depart of Military & Vet Affairs	2
Depart of Tourism & State Devel	5
Department of Agriculture	7
Department of Corrections	17
Department of Education	3
Department of Health	13
Department of Human Services	7
Department of Labor	24
Department of Legislative Audit	2
Department of Public Safety	14
Department of Revenue	13
Department of Social Services	30
Department of Transportation	49
Division of Criminal Investigation	1
Investment Council	1
Office of the Attorney General	5
Parks & Recreation Division	1
Public Utility Commission	1
SD Building Authority	1
SD Federal Property Agency	1
SD Retirement	1
SD State Fair Commission	1
State Fuel Sites	53
Unified Judicial System	1
Total	**440**

Table 3Hj- State Facilities within a 0.5 mile buffer of Railroad Corridors

State Facilities	Count
Army National Guard	12
Board of Eng & Arch Examiners	1
Board of Regents	51
Bureau of Administration	8
Bureau of Info & Telecomm	4
Bureau of Personnel	1
Depart of Environment & NatRes	3
Depart of Game, Fish & Parks	5
Depart of Military & Vet Affairs	2
Depart of Tourism & State Devel	4
Department of Agriculture	4
Department of Corrections	11
Department of Education	2
Department of Health	6
Department of Human Services	6
Department of Labor	19
Department of Legislative Audit	2
Department of Public Safety	7
Department of Revenue	9
Department of Social Services	14
Department of Transportation	22
Office of the Attorney General	3
Parks & Recreation Division	1
Public Utility Commission	1
SD Building Authority	1
SD Federal Property Agency	1
SD Retirement	1
SD State Fair Commission	1
State Fuel Sites	21
Unified Judicial System	1
Total	**224**

Table 3Hk- State Facilities within a 0.5 mile buffer of Highway Corridors

State Facilities	Count
Airport	1
Army National Guard	14
Board of Eng & Arch Examiners	1
Board of Regents	308
Bureau of Administration	9
Bureau of Info & Telecomm	6
Bureau of Personnel	1
Depart of Environment & NatRes	3
Depart of Game, Fish & Parks	6
Depart of Military & Vet Affairs	3
Depart of Tourism & State Devel	4
Department of Agriculture	7
Department of Corrections	13
Department of Education	4
Department of Health	13
Department of Human Services	6
Department of Labor	22
Department of Legislative Audit	2
Department of Public Safety	13
Department of Revenue	9
Department of Social Services	29
Department of Transportation	74
Division of Criminal Investigation	1
Investment Council	1
Office of the Attorney General	5
Parks & Recreation Division	1
Public Utility Commission	1
SD Building Authority	1
SD Developmental Center	1
SD Federal Property Agency	1
SD Retirement	1
SD State Fair Commission	1
State Fuel Sites	82
Unified Judicial System	1
Total	**645**